PYOGENIC INFECTIONS OF THE HAND :

AN INDUSTRIAL AND CLINICAL INVESTIGATION IN THE AFRICAN MINER

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C O N T E N T S

INTRODUCTION

The foundation of this study was laid early in 1961, when, shortly after I joined the mining industry, part of my duties entailed the care of the primary septic ward. At the time I was impressed by the large number of septic cases that were admitted to hospital, and by the universal use of antibiotics for even the most minor of cases.

With the encouragement of Mr. D. Evans, I undertook a pilot investigation with the twofold object of assessing the extent of the problem and the place and value of antibiotics in the treatment of cases. For this purpose, 480 consecutive cases were studied. Alternate cases were treated with antibiotics and without and the results of this aspect of the study will be dealt with in due course.

The distribution of the cases according to site of lesion was as follows:

Hand	172 (34%)	Head, face & neck	30 (6%)
Leg	100 (20%)	Trunk	29 (6%)
Knee	44 (9%)	Foot	23 (5%)
Axilla	40 (8%)	Arm	23 (5%)
Groin	30 (6%)	Genitalia	12 (2%)

Infections of the hand accounted for ⅓rd of all cases and were also responsible for the greatest number of complications and cases requiring prolonged stay in hospital.

It was found that many aspects of the problem of hand infections as reported in the literature were poorly understood and that many earlier incorrect views, particularly with regard to treatment, were being perpetuated. It was for these reasons and because unique opportunities existed for study of the population at risk and for observation of clinical aspects, that this investigation

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was undertaken.

Scope of the Investigation

The aim of this investigation is the study of a number of factors, both epidemiological and clinical, concerning pyogenic hand infections.

Environmental and personal factors are considered first (Section I), clinical aspects, including management and results, next (Section II) and finally a section III is devoted to anaesthesia, with special reference to 'intravascular regional analgesia'.

As extensive bacteriological studies have been made in the past (Williams and Miles 1949, Warren 1954, Elek 1959 and Wypkema 1965), no such investigations were undertaken, but the literature is reviewed because this aspect is pertinent to the understanding of the problem.

EPIDEMIOLOGICAL BACKGROUND

Gold Mining and Medical Services

Gold mining is the most important industry in the Republic of South Africa producing about 2/3rds of the free worlds total.

The number of Africans employed on the gold mines in 1964 was 380,000. There are 38 hospitals and they serve 62 gold mines. The total number of beds, including those of the Witwatersrand Native Labour Association hospitals, was 8,817 in July 1964. The majority of hospitals are staffed by full-time medical officers. In 1963 there were 100 full-time medical officers employed. In some of the smaller hospitals part-time medical officers are employed.

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The Importance of Hand Infections

Hand infections occur frequently in the gold mining industry. In this investigation the incidence was approximately 27 per thousand workers per annum. If this rate holds good for the other mines, it follows that some 10,000 hand infections are seen annually in the industry and a large number of these will be treated by a doctor working on his own. Hand infections are thus of considerable economic importance and although the cost of hand infections in the mining industry cannot be assessed exactly, it involves loss of production and human suffering.

The Population at Risk and Bacteria Concerned

Any epidemiological investigation and especially one associated with an industrial occupation, involves consideration of numerous factors that may be related to the cause and spread of infection.

In this investigation the population at risk belongs to various tribal groups from Southern Africa, working at 5,000 feet below the surface of the earth and largely isolated from the investigator by language barriers.

The group of organisms concerned in the disease process is notorious for its ubiquity and noteworthy for its variation in invasive power. The septic hand cannot be looked upon as an isolated incident, nor can it be regarded merely as a simple surgical problem. Some disturbance of equilibrium between bacteria and host must take place before disease results.

Site of the Investigation

This investigation was conducted on the 6 gold mines of

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the Anglo American Corporation of S.A. Ltd., at Welkom and Odendaalsrus and at the Ernest Oppenheimer Hospital, an 850 bed Industrial Hospital of the company serving these mines. The respective mines are Welkom, President Steyn, Free State Geduld, President Brand, Western Holdings and Freddies.

With the exception of 'Freddies', which was recently taken over from another company, all the mines were planned and started within a few years of each other. Being part of the same company, in the same geographical area, the mines have similar living quarters and working arrangements; but because of different geological formations, depth of mining and various other local factors, various differences do exist and these will be mentioned where possible.

Medical Services

Whereas each mine has its own management concerned with production, medical services on the six mines are all administered by the same medical department. At each mine there is a full-time Medical Officer in charge, and mine appointments and hospital posts are rotated periodically. These changes, together with regular staff meetings, ensure that matters related to health (housing, nutrition, hygiene, dressing stations) and hospitalisation, are constantly reviewed and standardised.

Employees are actively encouraged to report to the hostel dressing stations, which are in the charge of fully trained ambulance officers, for even the most minor injury or ailment. Treatment at the dressing station does not necessitate the loss of working time or remuneration to the worker. African employees who wish to see a doctor (and all who are so instructed) are seen

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daily by the Mine Medical Officer at the morning sick parade, and more urgent cases are sent to the hospital casualty department. This may or may not entail the loss of a working shift.

As no nursing facilities exist within the hostel rooms, the general rule is that anyone who is unable to work through illness or injury is admitted to hospital until fully fit to resume his normal duties. Clearly a man who does heavy manual work cannot do his normal work while he has a tender wound of his hand or fingers. A small percentage of special cases are allowed to remain on 'convalescent work', which consists of light duties under the supervision of the ambulance officer.

Hospitalisation

After the preliminary investigation in 1961 it was realised that hand infections should rarely, if ever, be treated at the dressing stations and since 1962 the vast majority of hand infections have been sent to hospital on the day they are first seen. This coincides with the experience of the American Army during World War II where hand infections were treated on an ambulatory basis until 1945 when because of the poor results obtained, all men with acute hand infections were hospitalised. (Hand Surgery in World War, II 1955)

The gold mining industry is fortunate in having these facilities; elsewhere hospital accomodation is usually at a premium and all but the most serious hand infections are treated on outpatient lines. In some places, special hand clinics are organised.

The Ernest Oppenheimer Hospital comprises 16 wards of equal size, each mine having its own medical and surgical ward.

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Some wards are shared by all the mines, e.g. the Tuberculosis ward. Two such special wards in which patients from all the mines are treated are the 'primary sepsis' and 'secondary sepsis' wards. This distinction is for administrative convenience, the inference simply being that 'secondary septic' cases are those in which trauma is obvious, sepsis having taken place after injury or treatment, while 'primary septic' cases are those in which trauma played no part or was of a very trivial nature. Though there is some overlap between these categories the system functions well in practice. Patients with hand infections are admitted to the 'primary sepsis' ward together with all the other abscesses, carbuncles etc. unless they very obviously belong to the 'secondary septic' category e.g. infection following a compound fracture.

Since 1961 I have been in charge of the 'primary sepsis' and 'secondary sepsis' wards when this study was being conducted.

THE PATHOGEN

Organisms from septic hands

The organisms isolated from septic hands are similar to those of other septic wounds. Most commonly the coagulase positive staphylococcus is isolated and occasionally coliforms and Lancefields group A streptococci. Other organisms e.g. Haemophilus influenza (Miller and Turk 1965) are rarely encountered.

Streptococci Streptococcal infections were formerly more important; they showed more clinical signs, spread readily and were frequently fatal (Koch 1934). The severity of many streptococcal infections has decreased during the past half-century. The explanation given is that, as streptococcal

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infections are common in crowded communities, a resultant increase in the resistance of the community, particularly to the erythrogenic toxin, has developed (Fairbrother 1955). Since the introduction of antibiotics, streptococci having remained sensitive to penicillin, have rarely been a cause of surgical sepsis in the last 15 years (Rountree 1951). Grumbach (1965) on the other hand holds that there is no adequate explanation for this decrease in streptococcal disease and attributes it to the natural waxing and waning of bacterial virulence.

Gram-negative organisms Investigating wound infections with gram-negative organisms, Florey, Ross and Turton (1947) found that the main features were lysis of surrounding clot, persistence of discharge and consequent interference with the processes of bony and soft tissue repair. The problem of their management was their tendency to chronicity and resistance to penicillin. In the present investigation the 'coliform' organisms constitute only a small number of the infections. As with the staphylococcus, infection of wounds with Coliforms usually results from auto-infection from the skin of the patient (Williams and Miles 1949, Topley and Wilson 1955).

Staphylococci As hand infections are most frequently a manifestation of staphylococcal disease, the literature has been studied in order to determine its occurrence, mode of spread and pathogenicity. Reference has been made to a bacteriological study of the aetiology and prophylaxis of infection and sepsis in industrial wounds of the hand by Williams and Miles (1949) and extensive reviews concerning the staphylococcus by Elek (1959),

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Wypkema (1965), and Warren (1954). A great deal of work has also been done on staphylococcal wound infections in hospitals (Williams, Blowers, Garrod and Shooter 1960, Ellacombe 1963, Freedman 1964). Staphylococci are universally found and they are an important part of our 'resident flora'.

Relation of Staphylococci to Disease

The control of the great plagues and certain acute bacterial infections has by contrast thrown into prominence other bacterial diseases that characteristically require a relatively greater reduction of bodily defence before infection can become disease. These attributes are shared by the staphylococcus, the bowel flora and the tubercle bacillus. With these organisms harbouring is commonplace but disease is rare (McDermott 1956).

McDermott further states that spread of diseases among a group of persons is not to be regarded as a visitation from without but rather as an indication that something is going wrong with the crude equilibrium that previously existed in the community. If this is so, it follows that we should not be exclusively pre-occupied with attempts to drive invaders out, for we are not really dealing with invaders but with original settlers. Our pre-occupation should be instead with attempts to discover what it is that goes wrong which permits these commensals to gain control. Staphylococci should be regarded as an endemic infection of our species.

Pathogenicity and Virulence

The most useful test for pathogenicity in a strain of staphylococcus is the coagulase test. Whether this property is

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of fundamental importance to the organism for its attack on the host is of secondary importance. It provides a means of distinguishing between potentially pathogenic organisms and those of similar morphology but not possessing the power to produce disease (Elek 1959).

Much has been said about so called 'virulent' strains of staphylococci in hospitals. Gould (1958) thought they resulted from the greater quantities of antibiotics used in hospitals thus freeing insensitive strains from competitors of lesser breeds. Virulence has also been associated with phage pattern e.g. Type 80, which is notorious in severe epidemics. McDermott (1956), however, contends that on the whole there is no convincing evidence that the hospital staphylococci are any more virulent for man than they were previously.

It is generally accepted that the value of phage typing lies in the practice of public health and the tracking down of a dangerous carrier.

Sources of Staphylococci

From a review of the literature it is apparent that for all practical purposes, staphylococci have no reservoir outside the human body. The true sources of the organism are carrier sites and septic lesions, which are the only places where the organisms multiply.

Of the carrier sites, the anterior nares would appear to be most important (Tulloch 1954, Williams et al. 1962, Elek 1959, Green 1961). Other important carrier sites are the skin of the hands (Williams and Miles 1949) and perineum (Bøe et al.1964). From these sites bacteria are dispersed into the environment by an

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egress in nasal secretions, contamination of the skin, clothing or bedding, release of organisms by friction, movement or washing and transfer to others by air currents (Hare and Thomas 1956, B.M.J. 1964 and 1965).

In bacteriological investigations on the gold mines, Warren (1954) found no staphylococci in underground water or air and only occasionally in passages on seats, rails etc. Organisms were more frequently found in sleeping quarters.

Staphylococci in the Atmosphere

In the environment, the organism persists for long periods in dust owing to its ability to resist drying at ordinary temperatures. With increasing relative humidity increased death rates of staphylococci are noted. Daylight, sunlight, ultraviolet light and fluorescent light destroy some of the bacteria (Lidwell and Lowbury 1950).

It is thought unlikely that wounds, with the exception of burns, can contract a staphylococcal infection from the air. Wallace and Daguid in 1952 demonstrated that on the average 0.46 particles containing pyogenic cocci settle per sq. inch per hour from air, and this low count makes direct aerial infection improbable.

Owing to the aerial condensation that occurs in the nares, the nose can become infected from the air and this in turn may be the source of infection of the susceptible victim.

The Carrier State

Staphylococci of some kind are normal constituents of nasal secretions, but the present basis of surveys is the finding of coagulase positive staphylococci in the anterior nares.

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Wypkema (1965) in his review of the literature found that 20-60% of normal healthy adults outside hospitals are nasal carriers of staphylococci and Elek (1959) states that 5-20% of persons are skin carriers. Findlay and Abrahams (1946) investigated 300 Africans (150 soldiers and 150 villagers) and found a nasal carrier rate of 27.3% and 11% of coagulase positive staphylococci. He also studied 100 Europeans and found no significant difference in the European and African carrier rates. In a similar community to the one in which the present study is conducted, Warren (1954) found a nasal carrier rate of 6% and a skin carrier rate of 24%. He explains his findings by stating that a far greater opportunity for person to person transfer of infection and more faecal contamination of the skin occur in his African group than in European communities studied.

According to Smith (1964) there are 2 stages in staphylococcal disease - a beach-head establishing the carrier state and an invasion of the body.

In adults the nasal carrier state depends not so much on the environment as on the person himself. Thus there is a tendency for a given person to be either a persistent carrier, or to be persistently free from staphylococci in the nose (Miles et al. 1944).

Carriers have been classified as follows: (Elek 1959).

Persistent carrier It has been estimated that about 30% of people in the world are persistent carriers. These people may stay positive for many months or even years and they also tend to keep the phage type.

Intermittent carrier These people have a constant exchange of

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staphylococci through periodic freedom from and re-infection with new flora.

Non carrier By careful and persistent technique these may in fact be shown to be occasional carriers.

Autogenous disinfection of the skin normally takes place through continual loss of superficial squames by wear and tear, general acidity of the skin, desiccation, secretion of certain fatty acids and certain other ill-defined bacterial agents (Payling Wright 1958).

Fresh sweat is said to be an excellent medium for bacteria, which grow even more freely in it than in broth (Elek 1959).

Some bacteria become established on the skin and these skin carriers may be classified as (a) superficial skin carriers, in whom staphylococci do not multiply and are easily removed by washing, antiseptics etc. and (b) deep skin carriers, in whom staphylococci live and multiply in sweat glands and hair follicles and are not removed by washing and antiseptics (Lowbury, Lilly and Bull 1964).

Infection from Carriers

The nasal carrier state has been shown to be an important factor to consider as a cause of hospital wound sepsis (Miles et al. 1944 Howe 1954, Williams et al. 1960, Gillespie 1961, Williams et al 1962). Work done outside the hospital environment however, does not always support this view. Williams and Miles (1949) and Warren (1954) consider that the skin carrier rate is more important in the production of boils and hand infections. Roodyn (1954)

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found that of 71 patients with boils, 32% carried no nasal staphylococci and 17% carried strains in the lesion that were different from those in the nose.

There is evidence that the carrier of one type is protected against the acquisition of another (Elek 1959) and Smith (1964) states that carriers should not be treated unless they can be shown to be causing disease in themselves or their contacts. Hospitilisation and antibiotics increase the carrier state, especially of resistant strains, by eliminating harmless bacteria.

Mode of Contamination and Infection with Staphylococci

Wounds are frequently contaminated at an early stage with pathogenic staphylococcus aureus (Williams and Miles 1949, Ellacombe 1963 and Wypkema 1965); and this has been termed 'silent infection'. All the available evidence indicates that the staphylococci in fresh wounds are largely derived from the patients own skin. The hypothesis of self contamination gains support from the observation that in most cases the staphylococci seem to have been introduced into the wound at the time of injury, although staphylococci are rarely found on the machinery or other object inflicting the wound.

In hospitals it has been shown that patients who become carriers are the most likely to develop wound sepsis; persistent carriers less likely, and non-carriers the least likely.

It is largely the mechanical strength of intact skin that protects the underlying tissues from bacterial invasion. Because of the exposed position of the skin it is frequently

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subjected to trauma and if the intact skin is broken it gives rise to a portal of entry for bacteria. The development of a clinical infection from a bacterial contamination is dependent on a number of interrelated factors, namely the invasive capacity of the organism, the resistance of the host, the size of the inoculum (experimentally the minimal pus-forming dose has been found to be high), the presence of physiological derangements (especially reduced blood supply), and the type of tissue involved.

BACTERIOLOGICAL TECHNIQUES

The bacteriological tests in this investigation were all carried out by the laboratory staff of the Ernest Oppenheimer Hospital.

Specimens on sterile dry cotton wool swabs were collected from the anterior nares (in the investigation of the staphylococcal carrier rate) and from infections at the time of incision (in order to determine the organisms present in hand infections and their characteristics). The collection was carried out in such a way as to avoid contamination of the specimens from other sources.

1. Specimens were initially cultured for 24 hours on a blood agar slope, a staphylococcus medium no. 110 slope, and a glucose-broth tube.

2. A subculture from the glucose broth tube was then set up on a blood-agar plate and tested against antibiotic sensitivity discs, which were either commercial preparations or prepared according to the method of Stokes (1960). Subcultures from the blood-agar slope or the staphylococcus medium were placed into broth tube and incubated for a further 24 hours. Gram stain smears for

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identification of organisms were made from the blood-agar slope or the staphylococcus medium.

3. After 24 hours the sensitivity plates were read and a tube-method coagulase test as described by Mackie and McCartney (1950) performed.

The results of bacteriological studies are reported later.

SECTION I

THE INFLUENCE OF ENVIRONMENTAL AND PERSONAL FACTORS ON THE OCCURRENCE OF HAND INFECTIONS

In this section an attempt is made to evaluate some of the factors influencing the occurrence of hand infections on the mines.

All patients with hand infections admitted to the Ernest Oppenheimer hospital during the year ended April 30th 1965 were classified and analysed and 1,382 patients who worked on the mines are discussed in this section.

Background information was obtained from the study of 1,000 randomly selected medical history cards of employees who had left the mines in the first few months of 1965; monthly returns to the hospital concerning mine complements; the Aptitude Testing Centre, the ventilation departments on the respective mines; hospital records and other relevant sources.

I have made several underground trips on routine visits to acclimatisation and other working sections and on rescue operations for accidents occurring underground and have thus gained first-hand knowledge of underground conditions and the various mining occupations. Regular dressing station visits and compound inspections afforded the opportunity of studying the living environment and general care of the employees.

THE EFFECT OF OCCUPATION

" 'When you come to a patient's house, you should ask him what sort of pains he has, what caused them, how many days he has been ill, whether his bowels are working and what sort of food he eats'. So says Hippocrates in his work Affections. I may venture to add one more question: what occupation does he follow?".

Bernardini Ramazzini (1700)

/It is.....

It is well known that a high incidence of staphylococcal skin conditions occurs in certain occupations.

A Medical Research Council publication (Collis and Llewellyn 1924) dealt with 'beat knee', 'beat hand', and 'beat elbow' in the coal-mining industry. 'Beat knee', which is an extension from a staphylococcal infection of a follicle to the adjacent subcutaneous tissues, has been shown by Watkins (1951) and Atkins and Marks (1952) in their study of coal miners to be associated with repeated trauma caused by kneeling. 90% of the cases occurred amongst face workers.

Warren (1954) showed that knee and shin guards used without the additional protection of long trousers actually increased the liability of boils developing at and around the knee.

In the gold-mining industry, I have observed that boils or abscesses frequently occur round the ankles of the Africans and are due to the chafing of boots worn without the protection of socks.

Evans (1938) described 'salt water boils' on the wrists and forearms of fishermen due to chafing by wet oilskins. Only those handling fish on deck were affected.

Wright (1944) described the importance of boils in nurses, stating that they caused the longest time off work.

'Oil acne' in machine operators due to the blocking of sebaceous glands and hair follicles by cutting oils is a well-known industrial hazard (Lloyd Davies 1957).

/Hand Infections.....

Hand Infections Related to Occupation

The importance of occupation in hand infections has been recognised (Collis and Llewellyn 1924, Williams and Miles 1949). Leaming et al (1960) stated that the greatest single group comprised of 'manual dirty' workers and Wilkes (1954) listed some of the occupations in which hand infections occurred. A more precise determination of this occupational risk has not been possible hitherto because of lack of knowledge of the population at risk.

Patients in the present series were classified in their various occupational categories and Table I gives a detailed analysis of hand infections by occupation. Incidence rates are not given in table I because the total mean complements of the occupations as cited were not obtainable and some of the groups would be too small for incidence rates. In table III (p25) however, a classification of underground workers is set out showing mean complements and the hand infection numbers and incidence rates.

Table I

Occupational Distribution of Hand Infections

UNDERGROUND			
Stoping, boss boy	7	Loco drivers	19
Development, boss boy	1	Pipes, tracks & ventilation	75
Other, boss boy	25	Construction gangs	3
Winch driver, stopes	141	Drains and sanitation	14
Spanner boy, stopes	91	Haulages other	1
Loader driver	3	Guard boys	8
Drilling machine, stopes	76	Pump chamber & storage dam	4
Supervision, boss boy	1	Artisans generally & underground salvage	31
Drilling machine, development	16	Special services (surveyors etc).	5
Diamond drilling	3	Stores & issues	2
Stope lashing, bar lashing	539	Material handling underground	14
Stope, other, (cheesa, vamping, sweeper)	23	Underground not elsewhere classified	60
Timber and stone walling packs	110	Shaft services, onsetter skips & cages	7
Stopes acclimatisation	12	Special services, boss boys	1
Development other	2	Acclimatisation boss boys	1
Spanner boy, development	5	Trainee other	4
Shaft & drive timbering	15	Hose boy	1
Conveyor belts	1		
Box boys & tips	18		

SURFACE	
Material handling, surface bank	1
Drill sharpening shop	1
Crusher & mill, generally	1
Crusher, sorting belts	4
Conveyor belts, surface other	1
Waste dumps	1
Reduction plant, generally	5
Cyanide workers	2
Stores	1
Timber treatment and timber yard	1
Medical services	3
Native artisans	6
Clerks	1
Cooks	10
Surface, other	2

(Not classified 3)

Illustrations of occupations.

From the following photographs of a selection of occupations, the degree of potential abuse to the hands in many instances, may be seen.

Fig. 1. ' New labour' learning the correct method of ' lashing' in the surface training school.

Fig. 2.

Winch Driver

Fig. 3. Machine operator, ' spanner boy' and supervisor.

Fig. 4. Pipes, tracks and ventilation gang.

Fig. 5. Loader driver

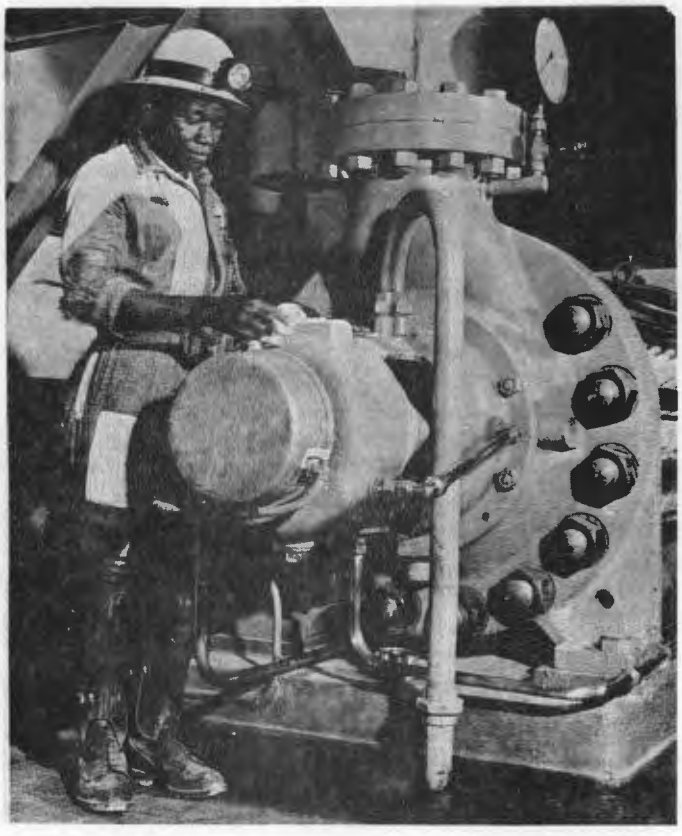

Fig. 6. Pump attendant.

Surface and Underground Occupations

Comparing hand infections occurring in underground and surface occupations (Table II) with the mean complements on the mines during the same period, it is calculated that underground workers are 6 times more likely to develop hand infections than those working on surface.

This difference is highly significant ($F = < 0.01$)

Table II

Hand Infections in Surface and Underground Occupations

	Hand Infections	Mean Complements on mines.	Hand Infection/ 1,000 Employees.
Surface	40	7,982	5.0
Underground	1,339	42,712	31.3

(3 not classified).

It is to be noted that out of the 40 surface employees with hand infections, 3 were medical dressers, 10 were cooks and 12 were employed in the crushing and reduction plant.

(a) Medical dressers handle all the septic lesions at the dressing station and have a greater risk of exposure to staphylococci than the remainder of the population. Dressers with septic lesions are also one of the possible sources of contamination of clean wounds treated at the dressing stations.

(b) Cooks. The effect of degreasing agents in destroying the natural barriers of the skin to infection is well known. Furthermore constant exposure to water through frequent washing and immersing of the hands causes maceration and subsequent cracking of the skin. Cooks work with foodstuffs and implements such as

/fish bones.....

fish bones, wire wool and knives, which may injure the hands and allow the entry of bacteria. Staphylococcal hand lesions in cooks are also one of the possible sources of contamination in the severe and sometimes fatal form of food poisoning caused by this organism. (Davidson 1956).

(c) Rock workers. Men working in the crusher and reduction plant are exposed to the risk of hand injuries in the handling of rock. The frequency of hand infections from this cause is dealt with in the chapter on trauma.

A knowledge of the working conditions on the mines suggests two main reasons for the marked discrepancy between surface and underground workers in their liability to hand infections, namely;

1. More severe demands on physical effort in difficult and confined spaces underground (and therefore increased liability to trauma).

2. Adverse climatic conditions underground. These will now be considered in more detail.

The Influence of Physical Effort

Watkins (1951) and Atkins and Marks (1952) were able to correlate the increase in the number of 'beat knees' with an increasing tonnage of coal per person.

In the job evaluation for assessment of wage rates for African underground workers, one of the factors considered by the management, is the physical effort that is required in each occupation. (Anglo American Corporation of S.A. Limited, 1964). In this assessment, occupations are given a factor ranging from

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0 to 20 depending on the amount of physical effort that is required. An occupation in which little or no physical effort is required, is assessed at 0 while progressively higher numbers are given for occupations in which greater physical effort is required.

In order to enable a comparison to be made, I have divided the occupations into related groups and assigned each group a 'physical-effort factor' derived from the Job Evaluation Schedule. A comparison of the incidence of hand infections/1,000 workers in the 10 main occupational groups is made in Table III.

Table III

Physical Effort in Occupational Groups
(Underground Only)

Occupational group	No. of hand infections	Totals employed	Hand infections/ 1,000 employees	Physical effort factor
Lashing (shovellers)	574	9,503	60.4	17
Timber & stonewalling	124	2,596	48.2	10
Winch drivers	144	3,621	39.8	11
Spanner boys	96	2,888	33.2	10
Drilling machine operators	95	3,823	24.8	10
Construction, material handling & transport	176	8,340	21.1	5
Miscellaneous	67	4,136	16.2	- *
Supervision underground	36	3,894	9.2	2
Haulages	15	2,157	7.0	4
Special services	11	1,816	6.1	2

* Factor not assigned

From this table it is apparent that physical effort plays an important part in the development of hand infections. A higher incidence is noted in occupations requiring more physical-effort, though differences in occupations with similar physical effort ratings, indicate that this is not the only factor.

/Conclusion.....

Conclusion Greater physical effort implies greater abuse and repeated trauma to the hands, with a correspondingly increased liability to hand infections.

Trauma in Hand Infections

The importance of trauma as a cause of sepsis in industry has been described (Collis and Llewellyn 1924, Williams and Capel 1945, Williams and Miles 1949) but no previous study appears to have been made concerning hand infections in the gold mining industry.

Background Information

The medical history cards, selected at random, of 1,000 employees who had recently completed their contracts (see p16) were studied. Information concerning any injuries sustained, infection resulting from trauma (secondary infection) and 'primary infections' (boils, abscesses, carbuncles and furuncles) of hands and other regions was extracted. This information includes details of patients treated at the dressing stations as well as hospital admissions.

In 434 (43%) cases trauma or infection occurred on one or more occasion during their contracts.

Injuries were recorded on 502 occasions (29 'closed' injuries and 410 'open' injuries) and of these 19 (3.8%) were recorded as having subsequently become septic.

Lesions that were septic when first seen at the dressing station numbered 188. Of these 50 were hand infections and 138 infections of other sites of the body.

An inspection of the hands of underground workers returning from their work, showed that the majority had evidence

/of minor.....

of minor cuts, scratches or blisters on their hands.

History and Evidence of Injury

Patients with hand infections were asked whether the infection had been preceded by any related trauma to the hands and if so the cause of the trauma. In addition the infections were examined for any evidence of injury, e.g. the presence of an overlying scar or blister (table IV)

Table IV

History of Injury

Cause of Injury	Number of Patients
Rock	198
Wire	127
Other (specified)	125
Other (not specified)	46
No history of injury	561
No record	325

Of the patients who gave no history of injury, evidence of injury was present in 119 cases.

Discussion

Gold mining in the Orange Free State is conducted in extremely hard and brittle quartzite and dolomite rock formations. The task of breaking down the rock involves drilling, blasting and the subsequent handling of large quantities of sharp rocks in confined spaces. Workers handling or coming into contact with these rock fragments are most liable to injury resulting in hand infections. This accounts for the very high incidence of hand infections in lashers (shovellers) and the unexpectedly high incidence in timber and stonewalling and supervision boss-boys

/noted.....

noted in table III. Spanner boys have a higher rate than the drilling machine operators, whom they assist, because they direct the drills and come into contact with the rock face. There is also a high incidence of hand infections in surface occupations where rock may be handled.

Scraper systems powered by winches and drawn by a system of wire cables are used to remove rock from the stopes. These cables are subjected to considerable wear and tear and invariably bristle with fragments of broken wire. They are commonly a cause of puncture wounds resulting in hand infections and account for the unexpectedly large number of hand infections in winch drivers (it is their duty to splice worn cables).

Other causes of trauma are less important singly and include splinters, 'packs', rails, pipes, machinery etc.

Eleven patients gave a history of injuries that were definitely not of occupational origin and these included 7 human bite infections.

Patients who gave a history of injury (496) and those who did not but in whom injury was apparent (119), numbered 615 or 58% of recorded cases (table IV). In these patients it was noted that the injuries were so trivial that the patient paid no attention to them and only reported for treatment because of the subsequent infection.

In the remaining patients, the mode of infection is probably similar to that of 'beat knee', namely an extension from a staphylococcal infection of a follicle into the adjacent subcutaneous tissue. Most staphylococcal infections of a single follicle quickly heal if the follicle and surrounding skin are

/protected.....

protected against friction and immobilised. In contrast, an infected follicle exposed to pressure, friction and movement heals slowly or may give rise to cellulitis or a boil, probably owing to the severance of the tissue barrier that normally confines such an infection (Atkins and Marks 1952).

My experience on the gold mines agrees with the findings of Williams and Capel (1945) who stated that 'trivial wounds are extremely common in the factory and that the great majority of small cuts do not become septic, even when untreated. It is in fact surprising that so few cases of hand infections are actually seen'. Furthermore, the great majority of septic lesions that are seen at the dressing stations, are septic when first seen.

These points are of importance when considering the management of cases and possible preventative methods.

Conclusion

Trauma is an important factor in the development of hand infections, either in the sense of a minor injury (most frequently caused by rock or wire) which becomes infected, or as an aggravating factor resulting in spread of infection from a follicle into the subcutaneous tissues. The great majority, however, of small cuts, abrasions or blisters do not become septic.

Climatic Factors

"Seasonal variations in the frequency of particular infective diseases are a commonplace of epidemiology. How far such variations are dependent on fluctuations in the average resistance of the host species, how far on the environmental factors that increase the opportunities for the spread of infection, and how far on factors the nature of which we cannot even guess, are problems to which we can as yet give no answer.

/Even if.....

Even if the occurrence of seasonal variations in resistance were clearly established, it would be an exceedingly difficult task to disentangle the various factors involved".
(Toply and Wilson 1955)

Underground climatic conditions on the gold mines are severe. Mining is conducted at great depths and because of the geothermic gradient, a linear increase in rock temperature occurs as one proceeds deeper down a mine. Naturally occurring water is present in large quantities in underground workings and large amounts are also used to suppress dust formation in drilling and other operations. Despite extensive and efficient ventilation, the heavy physical work of mining has therefore to be conducted under conditions of great heat and humidity.

Effects of Excessive Heat and Humidity

The stress and ill health that results from exposure to an atmosphere of low cooling power are well known (M.R.C. Special Report Series No. 298., Leithhead and Lind 1964, Macfarlane, 1965) and are of particular importance to the gold mining industry (King and Barry 1962, Barry 1962). For this reason well-controlled 'acclimatization' procedures are practised (Applied Physiology Laboratory 1958). Even in highly acclimatized persons, work output drops rapidly at temperatures above 85°F., and physical labour becomes virtually impossible at a wet-bulb temperature of about 95°F. (Coetzee 1965).

The skin, directly concerned in the regulation of the body temperature and having a protective function, is perhaps more affected by the burden of a hot, humid environment than any other system.

Deterioration in health of young men exposed to tropical

/climates.....

climates was thought to be the cause of an increased incidence of skin diseases and boils noted during the second world war (Cullinan 1946, Hill 1946).

Miliaria rubra is related to hot moist climates and the degree of acclimatization (Loewenthal 1961, Loewenthal and Hins 1964). Knowles (1944) found that dermatitis in coal miners was more likely to occur in hot pits.

Whitwell (1948) analysing the incidence of boils and hand infections in two factories, claimed that there was a seasonal incidence, but his evidence is unconvincing.

Investigating pneumonias over an 18 month period from December 1963, I found that a definite seasonal pattern could be demonstrated, most cases occurring in the cooler months.

The problem is complex and many factors have to be considered. Because in a hot environment men do not work efficiently (Wyndham 1961), they are more liable to injure themselves. Copious sweat is produced and the staphylococcus is said to grow very effectively in sweat (Elek 1959). On the other hand increasing relative humidity was found to result in increased death rates of staphylococci (Lidwell and Lowbury 1950) and this may partially account for the low nasal carrier rate found by Warren (1954) and again in the present investigation (6% and 8% respectively compared to 20 - 60% in other published series). Lidwell and Lowbury also confirmed the bactericidal effect of illumination.

Surface and Underground Temperatures

For the year ended 30th April 1965 mean stope-face temperatures from all the 6 mines and mean surface

/temperatures.....

temperatures from Free State Geduld only (morning and evening temperatures) were obtained from the ventilation departments. The results are given in table V, which shows the marked difference between surface and underground temperatures and also the seasonal variations in temperatures both underground and on surface. The coldest months underground are June, July and August and the hottest December, January and February.

Table V

Mean Stope-face and Surface Temperatures

Month	Mean Stope Face Temperatures (All mines)		Mean Surface Temperatures (F.S.G. only)	
	Wet Bulb °F	Dry Bulb °F	Wet Bulb °F	Dry Bulb °F
May 1964	84.3	87.3	49.6	57.6
June 1964	82.9	86.5	43.2	50.2
July 1964	81.3	85.5	42.4	50.3
Aug. 1964	82.4	86.1	46.5	55.1
Sept. 1964	83.1	86.4	51.5	64.1
Oct. 1964	83.5	86.5	56.8	67.2
Nov. 1964	84.3	87.4	60.4	72.6
Dec. 1964	85.8	88.2	61.9	73.0
Jan. 1965	86.6	88.9	63.2	73.6
Feb. 1965	85.9	88.6	63.4	76.4
Mar. 1965	85.2	87.6	69.3	88.9
April 1965	85.0	87.6	57.5	65.8

Seasonal Variation

The three monthly incidence of hand infections in underground workers from May 1964 to April 1965 are shown with the mean stope-face temperatures in table VI.

/From this.....

From this table it would appear that there is no seasonal

Table VI

Three-monthly Incidence of Hand Infections Compared with Mean Stope-face Temperatures

Months	May June July		August September October		November December January		February March April	
Hand infections	385		298		341		372	
Mean temperatures	W.B. 82.8	D.B. 86.4	W.B. 83.0	D.B. 86.3	W.B. 85.5	D.B. 88.2	W.B. 85.3	D.B. 87.9

(Temperatures recorded in ^{o}F)

incidence of hand infections related to underground temperatures (see also fig. 8).

It is probable that factors other than seasonal temperature variations (e.g. new labour intake, which is discussed later) are more important influences on the hand infection rate.

Hand Infections and 'Hotness' of Mines

When the incidence of hand infections in underground workers is compared with the 'hotness' of the mines (table VII, it

Table VII

Hand Infections and 'Hotness' of Mines

Mine	Welkom	Pres. Steyn	Pres. Brand	Western Holdings	Free State Geduld	Freddies
No. of hand infections	144	259	245	256	332	98
Mean underground complement (for same period)	6,652	8,869	8,224	8,760	7,735	2,472
Cases/1,000 underground workers	21.6	29.2	29.8	29.2	42.9	39.6
Mean underground temperatures (stope face)	81.4/ 83.4	84.1/ 87.3	84.0/ 87.7	83.0/ 86.1	84.5/ 88.2	87.2/ 89.6

(Temperatures recorded in ^{o}F)

/is seen that.....

is seen that the two 'hottest' mines, Freddies and Free State Geduld, have the highest rates of hand infections. Welkom, which is the coldest, has the lowest hand infection rate while President Brand, President Steyn and Western Holdings, with intermediate temperatures, fall between the coolest and hottest mines.

Two factors may be mentioned in explanation for this observation: Firstly, excessive heat and humidity, by lowering the resistance of the individual and causing excessive sweating, may result in an increased liability to boils and septic lesions; and, secondly, through inefficient work the employee is more liable to injure himself, thereby providing a portal of entry for pathogenic organisms. Valid statistical computation, however, is out of the question because too many factors are involved.

Conclusion No seasonal incidence can be demonstrated on the incidence of hand infections, but it would appear that hotter mines have a greater incidence of hand infections than cooler mines.

Length of Experience and Duration of Contract

Migratory Labour: 'New Boys' and 'Novices'

Because of legislation and custom dating back to the early days of gold mining, the African labour on the mines is largely migratory, and in comparison with other industries, a very rapid turnover of labourers has to be endured. The men sign on at the various recruiting agencies or at the mines themselves for contracts which are usually for 270 or 313 days

/and .....

and less frequently for 180 or 540 days. Occasionally the contract is renewed at the end of the stated time, but the vast majority of the men return to their homes for a time even if they wish to renew their contracts.

During the year ended 30th April 1965 the mean complement of the 6 mines was 50,694 Africans. During this period 41,240 men passed through the reception centre on new contracts ('new boys'), and of these 7,594 were men with no previous experience on the mines ('novices'). Thus there is roughly an 80% annual turnover of labour.

The ratio of novices to men with previous experience on the mines is 1 : 4.

Patients with hand infections were questioned on whether they had had previous experience on the mines or not and the hand-infection rates for the two groups were calculated. The results are given in table VIII which shows that novices

Table VIII

Hand Infections - Men with Previous Experience and Novices Compared

	No. of hand infections	Mine complements	Hand infections/1,000
Previous service	816	40,555	20.12
Novices	457	10,139	45.07

(No record - 109)

are 2.2 times more likely to develop hand infections than men with previous experience; this difference is highly significant ($P =< 0.01$). Part of the explanation for this is that men with no previous experience are more frequently placed in unskilled jobs requiring heavy physical effort.

/Time.....

Time of Contract

In table IX the cases are classified according to the time that had elapsed since the beginning of each individual's contract when his hand infection began. The same is shown diagrammatically in fig. 7. The first 3 months accounted

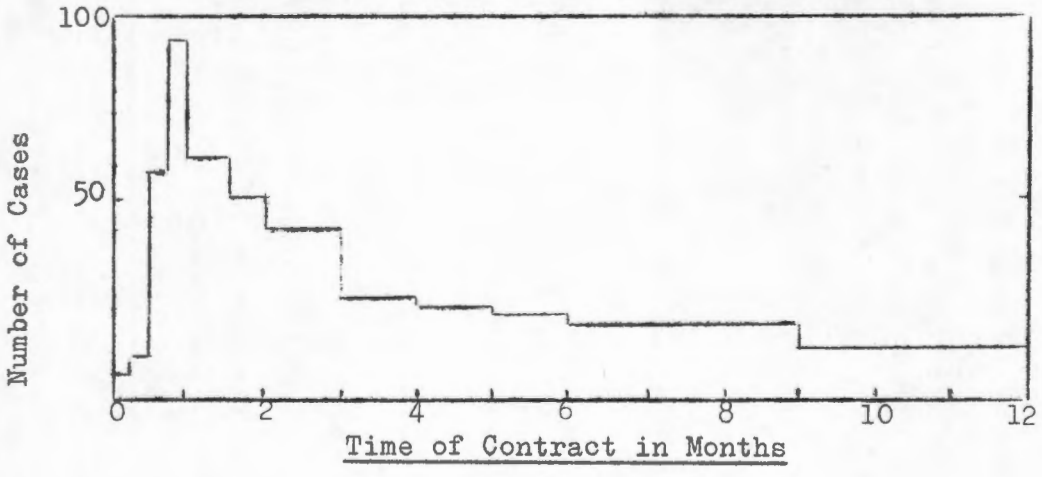
Table IX

Hand Infections and Time of Contracts

Time of Contract	No. of hand infections
1st week	5
2nd week	11
3rd week	58
4th week	93
5th & 6th weeks	125
7th & 8th weeks	102
3rd month	132
4th month	106
5th month	95
6th month	93
7 - 9th month	244
10 - 12th month	172
> 12 months	144
No record	2

Fig 7

Hand infections related to time of contract



for 526 (38%) of all hand infections. Miners are most liable to develop hand infections during the early part of their contracts,

/thus.....

thus showing that training and experience are important factors.

(It is interesting to note that in pneumonias the incidence rate is highest during the first week of the contract and tails off rapidly after the first month (van Niekerk 1965. Lobar Pneumonia Report).

Discussion

Whitwell and Sutherland (1948), studying boils and hand infections at 2 factories, noted a considerable increase in the rate related to demobilisation from the war and attributed this to the introduction of a high staphylococcal carrier rate into the civil community.

The present investigation shows that in the mines it is in fact the new engagement who is most likely to develop hand infections and least likely to cause increased infection in the established community.

Watkins (1951) in his study of 'beat knees' in coal miners felt that 'soft knees' in younger people is an important factor and that experience of the older worker and his willingness to take care of himself are also important.

It is likely that the lowered resistance of the labourer, subjected to unaccustomed physical and environmental stresses and repeated trauma to soft hands, unaccustomed to hard work, are the main factors responsible for the high incidence of hand infections in the men returning to the mine or joining the industry for the first time.

Conclusion. Miners on new contracts and especially men with no previous experience on the mines are more liable to develop hand infections. Hand infections occur most commonly in the early part of the contract.

/Fig. 8.....

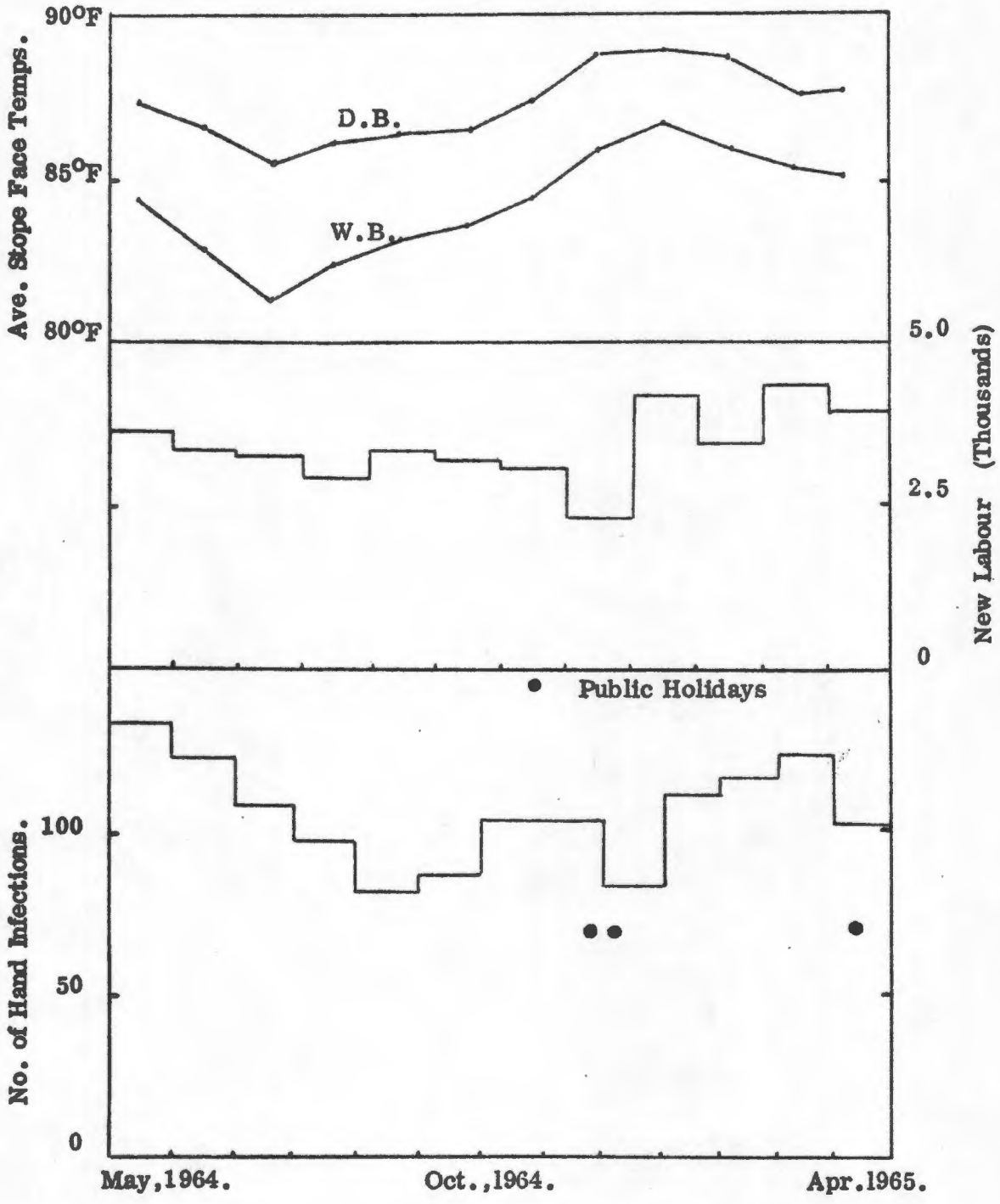


Fig. 8 : Composite figure with the 4-weekly number of hand infections and the main factors causing fluctuation namely : new labour intake and seasonal temperature changes - also public holidays.

(The 4-weekly, rather than the monthly number of hand infections is used, as the months have a varying number of days, in particular Mondays and Sundays, which would tend to distort the picture).

Patient-attendances by Day of the Week

Leaming and his co-workers (1960) noted from their figures that patients with hand infections delayed attending for treatment on Sundays, and that this was followed by a large attendance early in the week.

In the present investigation the attendances of new cases classified of the week are shown in table X for a period

Table X

Attendance by Days

Day of Week	Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
Hand Infections	13	349	253	187	199	200	176
Average Attendance	0.3	6.7	4.9	3.6	3.8	3.8	3.4

On the 3 public holidays, Wednesday 16 December 1964, Friday 25 December 1964 and Friday 16 April 1965, no new patients attended the hospital.

of 52 full weeks. It will be seen that on Sundays such attendances are extremely few and that on Mondays they are materially more than on any other day of the week.

On the mines, 6 full shifts per week are worked from Mondays to Saturdays, while no work is ordinarily done on Sundays. Employees are encouraged to report illnesses or accidents at any time of the week including public holidays and Sundays and facilities are readily available for them to do so. It is suggested that many patients who have early or established hand infections on Sundays are able to endure them by resting, hoping that the condition would have improved by the following day and that they would thus avoid admission to hospital.

/PERSONAL FACTORS.....

PERSONAL FACTORS

Tribal Origins

The gold mines of the Orange Free State draw their labour supply from far afield and from a diversity of tribes.

The cases of hand infection are enumerated in table XI according to the tribes to which the patients belonged, but it was not possible to obtain the exact numbers of employees from each tribe. Moreover, most of such numbers would have been too small for incidence rates to be determined. I therefore divided the tribes into two main groups that may conveniently be called 'tropical' and 'non tropical', from each of which the total number of employees was available so that incidence rates could be calculated (table XII). For this purpose 'tropicals' were taken as coming from north of the Tropic of Capricorn but including the whole of Bechuanaland and Portuguese East Africa, and 'non tropicals' from the remainder of Southern Africa (fig. 9).

Susceptibility of 'Tropicals' to Disease

It is generally believed by mine medical officers that the tropical African is less healthy than his non-tropical counterpart.

In 1961 I conducted an investigation to determine the incidence of anaemia and splenomegaly in new workers arriving on the mines; 328 men, consisting of 155 tropicals and 173 non tropicals were examined. Tropicals had lower mean haemoglobin readings (13.4 G% compared to 14.9 G%); 10% of the tropicals had haemoglobin values of less than 12 G% whereas no values of less than 12 G% were found in non-tropicals; and 10% of tropicals had

/palpably.....

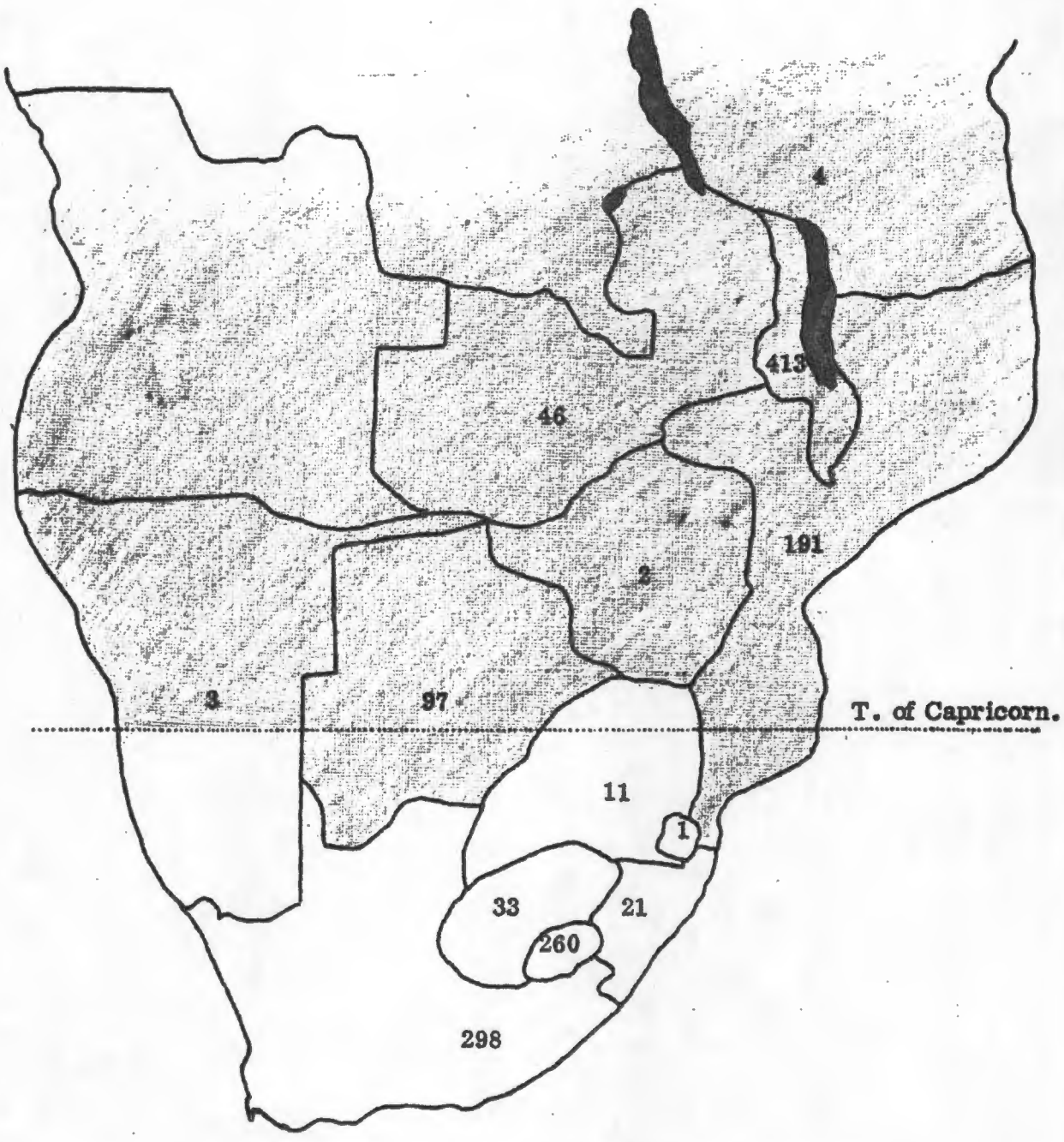


Fig. 9 : Southern Africa illustrating tropical regions (shaded area) and the number of hand infections from the major geographical areas.

palpably enlarged spleens whereas no enlarged spleens were found in non tropicals.

Tests for protein in the urine, included in the pre-employment examinations of new engagements, are more frequently positive in the tropicals; this finding is frequently associated with bilharziasis (King and Foster 1964).

In investigating a condition in which organisms similar to those found in hand infections are isolated, namely 'tropical myositis' or 'pyomyositis', I found that only 8 of the 103 cases diagnosed in 1964 were in non-tropicals.

In investigating pneumonia cases over an 18-month period from December 1963, I found that tropicals are more than twice as likely to develop pneumonia as non-tropicals.

These findings tend to support the generally accepted view that the tropical mineworker is less healthy than the non tropical.

Tribal Distribution of Hand Infections

/Table XI.....

Table XI

Hand Infections - Distribution by Tribes

Tropical		Non Tropical	
Group	No. of Hand Infections	Group	No. of Hand Infections
S. Rhodesia	2	Xhosa	189
S. W. Africa	3	Pondo	70
Bechuanaland	97	Pondomise	12
N. Rhodesia (T.A.B.N.)	4	Hlubi	15
(T.A.B.)	9	Baca	9
(T.N.R.)	33	C.P. Other	3
Nyasa (N.S.A.)	317	Natal. Zululand	21
(B.N.P.)	95	O.F.S.	33
(N.P.U.)	1	Basuto	260
Port. Nyasa	81	Ndebele	1
Port. E. Africa (T.M.P.)	16	Bapedi	1
(E.C.)	94	Tvl. Shangaan	6
		Tvl. Other	3
Tanganyika	4	Swaziland	1
Total	624	Total	756

(2 Not Recorded)

Table XII

Hand Infections in Tropicals and Non Tropicals
Compared to Mean Complements year ended 30th April 1965

	Hand infections	Mean complements (all mines)	Hand infections/ 1,000 employed
Tropical	624	23,747	26.3
Non-tropical	756	26,947	28.1

At first sight it would appear from table XII that the tropicals are less likely to develop hand infections than the non-tropicals. However, tropicals are recruited by the Witwatersrand Native Labour Association (W.N.L.A.) recruiting

/organisation.....

organisation and usually have contracts of 313 days compared to the non-tropicals, who are either recruited by the Native Recruiting Corporation (N.R.C.) or are locally recruited miners and usually have contracts of 270 days. There is thus a higher turnover of non-tropicals, which may be the cause of their apparently increased hand infection rate (64% of hand infections occur in the first 3 months of a 6 month contract).

Several unknown factors such as job placement, in tribal groups and the number of 'novices' in each group, may also affect this result. The former factor is unlikely to be of great importance, however, for men are placed in jobs according to their aptitude rating (Lake and Böhr 1960) and physical characteristics and not on a tribal basis.

Conclusions

Tropical Africans in general live in geographical areas in which endemic parasitic diseases such as malaria, schistosomiasis and hookworm are rife. Poor diets undermine their health and they also have a greater climatic change to contend with.

Although the tropical African is clearly not as healthy as his non-tropical counterpart, the hand infection rate is not affected to the same extent as other diseases, suggesting that factors related to the working environment are more important.

Age Distribution

The Influence of Age on Infections

It is generally held that the age extremes, the very young and the aged, are more prone to develop infections. The Mines and Works Act of the Republic (1956) prohibits the

/employment.....

employment underground of anyone under the age of 18 years. Young persons are therefore excluded from mining and the population consists mainly of young adults in whom obvious pathological conditions have been excluded by pre-employment examination.

Older people who were subjected to surgical operations had a strikingly more frequent incidence of sepsis (Williams et al 1960) and Wypkema (1965) found that patients over 50 years have a higher incidence of severe septic injuries.

In an exhaustive investigation of pulmonary tuberculosis on the mines, Laing (1965) found a much higher rate in the older age groups.

With advancing age a decreased susceptibility to those infectious diseases that confer specific immunity is likely. Infections caused by the normal bacterial flora of the body, however, are not usually associated with prolonged specific immunity and the resistance of older people to these organisms is likely to be decreased by defects in the mechanical and physiological mechanisms for controlling infection.

The lessened resistance of older people may be due to poor nutrition; poor circulation, especially of the extremities; drying and thinning of the skin layers and lower standards of cleanliness (Zeman 1954, Vickers and Sneddon 1956, Bradshaw 1960, Cayer 1960). It is well known that once infection is established in elderly patients it is often tolerated poorly and that the manifestations are also somewhat different (less febrile response etc.)

Wypkema (1965) and Leaming and his co-workers (1960)

/recorded.....

recorded the highest incidence of hand infections in the age groups more prone to injuries (20 - 50 years and 21 - 30 years respectively).

Williams and Miles (1949) state that the incidence of sepsis in industrial wounds bears no relation to the age of the patient while Atkins and Marks (1962) observed that the highest incidence of boils and carbuncles occurred during puberty. Previous writers were unable to compare hand infections with the population at risk, however.

Age Distribution of Hand Infections

Table XIII shows the age distribution of hand infections in the present investigation and also in the sample of the total personnel of the same mines (the Orange Free State gold mines of the Anglo American Corporation of S.A. Limited) compiled by Laing (1962).

Table XIII

Age Distribution of Hand Infections

	No. of hand infections	Hand infections % of total	Age distribution sample (Laing)		
			% of surface	% of underground	% of total
17 yrs. & under	10	0.8	0.3	0.4	0.4
18 - 20 Yrs.	204	15.4	17.2	11.4	12.3
21 - 25 Yrs.	563	42.6	23.6	33.0	31.5
26 - 30 Yrs.	310	23.4	17.2	27.5	25.9
31 - 35 Yrs.	133	10.1	13.5	11.9	12.1
36 - 40 Yrs.	69	5.2	10.3	9.1	9.3
41 - 45 Yrs.	19	1.4	6.1	4.1	4.4
46 - 50 Yrs.	11	0.8	6.7	2.2	2.9
51 - 55 Yrs.	2	0.2	2.5	0.4	0.7
56 Yrs. & over	2	0.2	2.5	0.1	0.5

(Not recorded 59)

/African.....

African labourers working on the mines come from backward communities and often have no idea of their age. When patients did not know their age an estimate was made. These figures though necessarily giving only a rough guide, are accurate enough to afford a reasonable indication of age distribution.

Table XIII shows that the 21 - 25 year age group constitutes a higher percentage of total hand infections than any other 5 year age group. According to Laing's figures this percentage is greater than the percentage that the same age group constitutes of the total mine complement (42.6 : 31.5) whereas in every other group except 18 - 20 years (15.4 : 12.3) the percentage of infections is less than the percentage of the mine complement. Experience shows that 21 - 25 (with some at 18 - 20 years) is the group of young men who have not had long experience on the mines and are employed especially in unskilled work requiring heavy physical effort.

The older worker is protected in several ways. It can be seen from the age distribution sample that most of them work on surface. When they are employed underground, they are generally given work which is supervisory or requires light physical effort. It is therefore not surprising that so few hand infections are seen in the older workers in spite of the fact that they are regarded as being more prone to develop infections.

Conclusion

Hand infections on the mines occur most frequently in the age group which does harder physical work and is more prone to injury i.e. 18 - 25 years. (For the influence of age on the

/lost shift.....

lost shift rate, see also 'results of hand infections' in Section II).

Physique

Except for weight loss as the result of some debilitating disease or malnutrition, it was not anticipated that physique would influence the hand infection rate. Heights and weights of patients were nevertheless recorded and compared with the standard heights and weights as drawn up by Laing (1962).

The results are given in Table XIV.

Table XIV

Heights and Weights of Patients with Hand Infections Compared to Standard Tables

Height

		Mean	S.D.
Hand infections	All cases	67.4"	2.5
Standard tables	Tropical	66.1"	2.5
	Non-tropical	66.3"	2.6

Weight

		Mean	S.D.
Hand infections	All cases	133.4 lbs	14.1
Standard tables	Tropical	132.4 lbs	13.5
	Non-tropical	133.8 lbs	15.6

(S.D. Standard deviation)

It has been shown that the prevalence of hand infections is highest in the age groups 18 - 25 years and it is known that these are the inexperienced young men who are given heavy physical

/work.....

work with a high risk from the point of view of hand infections. The standard tables show that on the mines the younger men weigh less than older men of the same height and this accounts for the discrepancy between the height and weight compared to the standard tables. These findings are therefore again a reflection of the population at risk rather than the influence of physique.

Conclusion

Physique does not appear to be a factor influencing the occurrence of hand infections.

Personal Predisposition and Other Factors in Susceptibility to Infection

Although an essential factor in hand infections is the introduction of infection, a combination of circumstances has an important influence in determining whether bacteria gain entry and become established. Why, when so many people are exposed to the predisposing causes and the infecting organism, so few develop hand infections, remains one of the questions in host pathogen relationships that are difficult to explain.

The General Condition of the Patient

Anything that lowers the general resistance of the patient makes it more likely for him to develop an infection when the required predisposing causes are present.

Fatigue and stresses induced by environmental changes play an important role; they have been discussed in the preceding part of this section.

The nutritional state, in particular vitamin and protein

/deficiencies.....

deficiencies, are recognised causes in reducing the resistance of the patient. Feeding on the mines is of a high standard and adequately supplies all dietary needs. Some of the men recently engaged on the mines, however, may well have deficiencies of a minor degree (overt deficiency diseases could be detected at the various pre-employment medical inspections).

Chronic diseases e.g. diabetes, nephritis, tuberculosis, carcinoma, recurrent infections, anaemia, blood diseases and peripheral vascular disease are important factors, but are infrequent on the mines because of the pre-employment examinations and regular subsequent supervision.

The influence of age has already been discussed.

FACTORS INFLUENCING LOCAL INVASION

1. Bacterial Invasion and the Carrier State

It has been shown in the review of the literature that patients who are nasal and skin carriers of staphylococci are more liable to septic lesions and wound infections than persons who are not carriers.

Warren (1954) in his investigation on two Transvaal gold mines found a nasal carrier rate of 6% (compared to the literature rate of 20 - 60% nasal carriers outside hospitals).

As part of the present research, an investigation into the staphylococcal nasal carrier rate was conducted between March and May 1965, with the object of determining the rate on engagement and again after a few weeks on the mine. For this purpose, nasal swabs were taken on engagement and were cultured

/for staphylococci.....

Table XV

Staphylococcal Nasal Carrier Rate
(Coagulase positive organisms only)

	On Engagement	After 4 weeks
No. of Cases	220	190
Carriers	39 (17.7%)	16 (8.4%)

(22% of the carriers on engagement were positive again on the second occasion)

for staphylococci. Tests were made to distinguish coagulase positive from coagulase negative staphylococci. The procedure was then repeated in the same employees after 4 weeks though a smaller number were examined on the second occasion because of difficulties with shifts. The results are given in table XV.

The higher staphylococcal nasal carrier rate on engagement is probably a result of the crowding that prevails in the 1 - 2 weeks it takes for recruits to be transported from their homes to the mines. Thereafter the carrier rate approximates more to the rate found by Warren on the mines and raises the interesting question whether the underground environment does not actually discourage the growth of staphylococci, thus causing a reduction in the nasal carrier rate.

From these admittedly inadequate figures it would seem that some of the carriers tend to remain positive carriers - a fact well documented in the literature.

Pathogenic organisms are generally transient residents on the skin surface. These organisms, loosely attached by grease, fat and dust, are easily removed along with dust and emulsified fats by washing with soap (Lowbury et al 1964). Insanitary

/personal.....

personal habits or prolonged association with organisms may result in their becoming firmly adherent to the skin, in the follicles etc. and being incorporated in the resident skin flora. When the opportunity arises they are readily available for invasion. Pyogenic infection is in this way associated with dust, dirt and insanitary personal habits (Price 1944).

2. Greasiness and Dryness of Skin

The greasy skin of the seborrhoeic subject is particularly prone to infection (Knowles 1944). It is generally accepted that the mechanical plugging of follicles by sebaceous material and the formation of a nidus for bacterial growth is responsible. Atkins and Marks (1952) during an investigation into beat disorders in coal miners, found that men with greasy skins were particularly prone to staphylococcal infection.

Degreasing of the skin results in the loss of fats essential to the maintenance of skin health. Drying and cracking of the skin surface and follicular abnormalities occur. As a result of these factors and the lowered skin resistance that accompanies disturbances in the protective acid mantle, pyogenic infection is facilitated.

Thus staphylococcal infection is associated with excessive oiliness or dryness of the skin surface.

3. Wound Susceptibility

While any trauma predisposes the patient to sepsis, local factors of wound susceptibility depend on the presence of necrotic and potentially necrotic tissue, exudative complications (haematoma, seroma) dead spaces, time and area of exposure and

/foreign.....

foreign bodies (Wypkema 1965). Of the local factors, the blood supply is the most important (Payling Wright 1958).

Personal Predisposition - Recurrent Infections

There is a small group of patients whose wounds always seem to be complicated by sepsis or who get repeated attacks of furunculosis and boils for no apparent reason. To what extent this personal predisposition or idiosyncrasy is due to one or a combination of the factors discussed in the foregoing chapters or other unknown predisposing factors is not known.

In the analysis of 1,000 medical history cards of miners who had completed their contracts, there were records of 50 hand infections and 138 septic lesions of other sites. Infections on more than one occasion were noted in 29 individuals (accounting for 71 infections). In 13 patients hand infections were either preceded or followed by further hand infections or other septic lesions. Furthermore 1 patient had 6 episodes of septic lesions at various times during his contract, another had 5, two had 4 each and a further 2 patients had 3 episodes of septic lesions each.

A small group of patients thus appear to be particularly liable to septic lesions in general and to hand infections which are a part of the whole picture.

Roodyn (1954) reported that people with recurrent boils may find themselves suddenly cured and this may be due to the raised antibody titre. This immunity apparently does not develop if antibiotics have been given.

PREVENTION

GENERAL MEASURES

1. Mining Techniques

From the preceding findings and discussions it is clear that to remove the important predisposing factors in the development of hand infections, would require a revolution in the whole mining industry. Thus in order to reduce the repeated minor trauma to the hands mechanisation must be increased. This is in fact already being done to increase efficiency and to cut labour costs. However, by the very nature of the work and type of material that is being handled, considerable abuse of the hands will always be inevitable.

2. Recruiting

The migratory labour system, especially of high-risk labourers from outside the Republic of South Africa, results in a high general morbidity; the hand infections in this investigation being only one aspect of the problem.

3. Working Environment

Improved ventilation, would bring about an improvement of the heat illness rate (Barry 1962, King and Barry 1962) and also decrease the incidence of hand infections and probably other diseases. Through the beneficial effects on the general well being and general efficiency of the labour force, the morale, efficiency and general morbidity could be favourably influenced.

Better lighting would also improve overall efficiency and reduce injury (Weston 1962, Kethro 1963).

/Living.....

4. Living Environment

The need for the prevention of overcrowding and the provision of adequate washing facilities, adequate feeding and recreational facilities, speaks for itself. On these points no effort is spared by the mines and a high standard of general health measures is maintained.

5. Education and Supervision

Education and supervision of the workers in matters of work and general health is of prime importance. If the job is done carefully, injury rates will be reduced. Workers should be educated in the importance of personal cleanliness and washing of the hands should be stressed.

6. Medical Care

The importance of the care of all minor wounds has been emphasised (Wilkie and others 1923, Koch 1941) Chapman and Kark (1957) advocated the use of prophylactic penicillin for all minor wounds of the hand as a measure against hand infections, but in the light of recent knowledge this practice is to be condemned. Ellis (1951) discussing the outpatient treatment of the infected hand, concludes that penicillin has no value in minor injuries and Schonholtz et al (1962) in their study of the effectiveness of prophylactic anti-biotics in orthopaedic surgery, concluded that there was no evidence that the incidence of wound sepsis was influenced.

In their study of sepsis in industrial wounds, Williams and Capel (1945) noted that trivial wounds are extremely common in the factory and that the great majority of septic lesions that are

/seen in.....

seen in the surgery, are septic when first seen. Furthermore the treatment of all trivial cuts in the surgery would demand a large increase in staff and costs and would lead to an intolerable loss of working time, while it is doubtful if the sepsis rate would be materially reduced.

From the study of 1,000 medical history cards, these latter views appear to be supported in that injuries requiring attention very seldom became septic, (19 cases or 3.8% of injuries). The majority of cases of sepsis resulted from insignificant injuries or occurred without any apparent injury (188 cases). These people reported with sepsis already established.

The experience of the United States Army agrees with these findings (Hand Surgery in World War II 1955).

With the co-operation of the mine management, I instituted daily hand inspections as the workers came off shift on one of the mines for a period of some months. The objectives were (a) to detect all hand injuries early and to treat them in the hope of reducing the infection rate, and (b) to detect all hand infections early and to treat them at the stage when they are most amenable to treatment. It soon became evident that, if this scheme were to be made completely effective, the number of minor wounds that would required to be treated would be completely unmanageable and that, with the dark skins and dirty hands, many injuries were in any case being missed. Even more significantly, it was found that, in general, patients with hand infections did report early, but were sometimes merely dressed at the dressing station and returned to work, resulting

/in delay.....

in delay of adequate treatment and an increase in complications.

Thus education of the worker, encouraging cleanliness and early reporting of injuries or sepsis, is important, but equally important is education of the medical personnel in the importance and in the general care of the injured and infected hand.

7. Placement of Workers

Patients who develop repeated septic lesions, especially those employed underground, should, with the co-operation of management, be placed in jobs where they have less likelihood of coming into contact with factors predisposing to infections.

PROTECTIVE CLOTHING

To admit that protective clothing is needed in the prevention of hand infections is really an admission of failure. Sir Thomas Legge's famous dictum for the prevention of accidents cannot be too strongly emphasized:

"If you can bring some influence to bear external to the workman (that is, one over which he has no control) you will be successful; and if you cannot, or do not, you will never be wholly successful".

We must ask ourselves first what hazards we are trying to protect the workman against; and the main hazards with respect to hand infections are (a) cuts and abrasions by rock, (b) blisters from handling shovels, drilling machines etc., and (c) puncture wounds by wire or rock.

It is to combat these hazards that gloves are issued. No standard practice exists on the mines and the number of gloves

/and the.....

and the type provided vary considerably from mine to mine. The most commonly used glove is a short plastic coated fabric type while a leather gauntlet-type is used to a lesser extent. Both suffer from the same drawbacks, namely inability to perform relatively fine movements and discomfort due to the high temperatures and humidity underground. Because they are a hindrance and are uncomfortable, they are frequently discarded by the workers. Gloves will only be of value if the workers are repeatedly educated in their value and correct use and if they are comfortable and effective.

Warren (1954) found that the underground use of knee/shin protectors by all underground workers is not justified and in many instances is contra-indicated; and that whatever protective clothing is used, the rubber (or plastic) protectors should not be worn in direct contact with skin, especially during underground work. O'Brien (1947) stated that clothes may be directly associated with staphylococcal infections of the skin under certain circumstances. Direct friction at the openings of sebaceous and sweat glands, minor abrasions and maceration of the skin (from excessive sweating beneath clothing in hot humid environments) are regarded as responsible factors. It has been shown that degreasing of skin (with subsequent concentric keratosis, folliculitis and furunculosis) may be caused inter alia by friction from clothing (O'Brien 1947).

From observation of the cases of hand infection occurring on the mines, I believe that grit, which inevitably gets between the gloves and the hands is often the cause of the

/initial.....

initial lesion allowing the entry of pathogenic bacteria. This would seem to be true especially in the case of infections round the wrist.

As in other industries, the use of gloves may actually impede the work. Winch drivers are unable to do the splicing of broken cables while wearing gloves, which therefore cannot be worn in the very circumstances in which they are most necessary.

A further point to consider, is that protective clothing often harbours pathogenic organisms (Laing 1963).

The following conclusions may be drawn:

Protective gloves often fail in their purpose because they are uncomfortable and are not used. In some instances they may be directly responsible for septic lesions of the hand.

The present types of gloves available are unsatisfactory (though the leather glove is a distinct improvement on the plastic covered type) and a need exists for ligher, cooler, better fitting and more flexible gloves.

Though workers engaged in high risk occupations, especially lashers, would benefit most from the use of protective gloves, I believe that beneficial results would be obtained by issuing gloves to all underground workers, to be carried with them and used whenever they handle rocks or implements.

Prevention of Staphylococcal Disease

In discussing the problem of staphylococcal infection, McDermott (1956) states that we are still almost wholly ignorant of the mechanics of staphylococcal infection and disease. Until

/we can.....

we can discover more concerning what determines the pathogenicity of certain staphylococci and how the healthy host manages to live in peace with them, it is not likely that the situation will materially improve. He also notes that as staphylococci are so ubiquitous, an approach based on attempts to eliminate them from the environment would not seem hopeful.

SECTION II

HAND INFECTIONS - CLINICAL ASPECTS

The material concerning the clinical aspects of hand infections, as analysed and discussed in this section, was collected during the year ended 30 April, 1965. Generally accepted principles are discussed and new observations and views that have been evolved over a period of 5 years are incorporated.

Only cases I managed personally are included in the analysis. There was no selection of cases and the 1,278 cases analysed are a true reflection of the patients treated at the Ernest Oppenheimer Hospital.

After the recording of information was begun, it became apparent from time to time that further details, e.g. the degree of oedema, would be useful and this was added to the basic pro-forma. Where information is given as not recorded, it is usually because of this subsequent attention to details that was not particularly looked for in the earlier cases.

HISTORICAL BACKGROUND

"In the development of this case history I hope to point out some of the factors involved in all research - specifically, the dependence of scientific progress on knowledge and concepts provided by investigators, past and present, all over the world; on the free interchange of ideas within the international community; on the hybrid vigour resulting from cross-fertilization between disciplines; and last but not least, on chance, geographical proximity and opportunity".

(Edward L. Tatum 1956, on the occasion of his receipt of the Nobel prize in medicine and physiology)

/The discovery.....

The discovery of anaesthetics and the development and understanding of bacteriology in the 19th century set the stage for major surgical advances. The hand however was largely neglected and up to the time of the first world war, hand injuries and infections did not receive any special attention and disability resulting from them was left untreated.

Kanavel's classic book 'Infections of the Hand' first appeared during world war I. Marc Iselin, of Paris (sometime pupil of Sterling Bunnel), in 1932 published a monograph on hand care. Kanavel and Iselin are regarded as being the most important contributors to the understanding of hand infections before world war II. In South Africa, attention was drawn to Kanavel's work and ideas by Ross in 1924.

During the period between the world wars, the study of the hand as a separate speciality gradually emerged, with Bunnel figuring prominently in the field of reconstructive surgery.

In the pre-war, pre-antibiotic era, hand infections caused a great deal of concern, for the dreaded spread of infection, against which surgeons could do very little, often resulted in extensive disability and even mortality. Iselin (1940) reports that in Zurich between 1920 and 1930 wounds of the fingers accounted for the greatest mortality (17 deaths) and compound fractures of the femur took second place with 7 deaths.

Because of this overriding fear of spreading the infection, a system of indirect incisions for drainage was developed. These incisions traversed healthy tissues,

/endangered.....

endangered nerves and vessels and because they did not remain open necessitated the use of rubber strips to maintain drainage. Astringent solutions damaged healthy tissues. Soaks, wet dressings, poultices, dry heat, hot lamps, partial venous stasis and other methods were employed, all in the hope of localising the infection.

Kanavel (1960) initiated the anatomical studies of hand infections by injecting radio-opaque material into the hand thereby defining various spaces and planes of spread.

According to Flynn (1943) the first major breakthrough in antimicrobial therapy was the synthesis of prontosil in 1932 by Mitzsch and Klarer and its use in puerperal sepsis by Colebrook and Kenny in 1936. Subsequently it was used with excellent results in the lymphangitis of hand infections.

The second world war gave a tremendous impetus to the study of hand infections. It was soon realised that even the most trivial hand infection badly treated resulted in prolonged disability, and the practice of treating hand injuries in special units was established - a practice continued in the post war period in the form of special hand clinics.

The discovery of penicillin, which was first used in war wounds in Sicily in 1943 (Cairns 1947) heralded in the era of antibiotics.

The stage was set for the intensive study of hand infections in the immediate post-war period and early 1950s.

GENERAL ANATOMICAL CONSIDERATIONS

The hand is a grasping mechanism and is also the main tactile organ of the body.

/Infections.....

Infections first become established in the skin and subcutaneous tissues and the final outcome depends largely on the initial anatomical site of the infection.

The skin of the volar surface of the palm and fingers is tough and thick to withstand hard wear and is upholstered beneath by a tough buffer of fat. A series of creases allows for movement on making a fist. The distal 2 volar creases crossing each finger are associated closely with the sheath of the flexor tendon without the intervention of subcutaneous fat. Injuries or infections at these creases may involve the tendon sheath and the creases also act as a barrier to limit the spread of subcutaneous infection (Bunnell 1956).

Fibrous bands and septa connecting skin to periosteum are present at the distal volar pad of each digit (pulp) and in the palm where they constitute the palmar aponeurosis. These inelastic structures do not yield to inflammatory swelling and the consequent increased pressure is an important factor in causing spread of infection and necrosis of tissues.

On the dorsum of the hand the skin is thin, soft and pliable and so is the subcutaneous tissue. When an object is grasped or the fist is closed, the skin is stretched tightly over the metacarpo-phalangeal (MP) and interphalangeal joints. At this stage the (MP) and proximal interphalangeal (PIP) joints are particularly vulnerable to penetration by sharp objects.

In 1878 Cleland described 'skin ligaments' now known by his name, which form a fibrous septum just dorsal to the neurovascular bundles of the finger and bind the skin of the

/neutral.....

neutral line to the side of each phalanx. These ligaments limit the spread of infections from palmar to dorsal aspect and viceversa.

The bones and joints are firmly secured by ligaments so that the carpus as a whole forms a strong bony and fibrous mass, concave on its palmar aspect, the flexor tendons and their sheaths occupying the concavity.

The volar aspect of the hand carries the main arterial supply which anastomoses very freely. Venous return is by way of the dorsum, to escape the pressure of the palm which would constrict the veins.

Infections of the wrist have been included in this series because they result from chafing by glove and grit.

Anatomical features are considered in more detail in the relevant chapters.

CLASSIFICATION

The object of a classification is to evolve a system whereby some estimate may be made regarding the evolution and prognosis of the disease. Such a classification should furthermore give a clearer idea of the disease and be based fundamentally on a knowledge of the pathological processes involved, which should be correlated with the clinical signs, so that the clinician can depend upon his own observation for diagnosis.

A classification, if it is to have maximum usefulness, should also be a guide to treatment and make possible an estimate of the probable course and final outcome of the disease. Accurate diagnosis based on such a classification will also define the prognostic status of each case.

/Iselin (1940).....

Iselin (1940) and the other earlier writers extensively used descriptive terms, e.g. phlyctenoid, anthracoid and gangrenous whitlows but also recognised the importance of the anatomical site of the infections.

In modern times the classification of hand infections remains a mixture of descriptive terms and clinical entities, e.g. carbuncle , cellulitis, subcutaneous and subcuticular infection , together with anatomical sites e.g. pulp abscess. The interpretation of the various categories is therefore liable to individual variations which make it difficult to compare types and results of infection in published series. I have advocated the adoption of a purely anatomical classification without the use of descriptive terms (van Niekerk 1964 and 1966) because this ties up well with the aetiological and practical features.

As has been noted earlier, the infected hand cannot be looked upon as an isolated incident, for it has associations with pyogenic infections elsewhere in the body. It is because of the unique anatomical structure of the hand, which influences the course of infections in that region, and its important functions that so much attention is focused on the problem of hand infections. The anatomical site of the infection largely determines its special features, course and special liability to complications.

In the first instance, the infection is confined to the skin and subcutaneous tissues. This applies equally to the infection introduced by injury or through the skin appendages. The first part of the proposed classification is therefore a

/description.....

description of the primary site of the infection in the skin and subcutaneous tissues.

Spread or extension of the infection may take place through the soft tissues (cellulitis) or to adjacent structures (bone, joint or tendon sheath infection). More remote spread may occur via lymphatics or the blood stream. These, in general, are the complications of hand infections.

The infection is thus firstly described in relation to the skin and subcutaneous tissues and secondly its complications. This method of description is followed in the following proposed classification.

Proposed Classification of Hand Infections

VOLAR

Finger - Pad - Distal (pulp)
- Middle
- Proximal

Crease - Distal
- Middle
- Proximal

Palm - Palmar pad
- Web
- Thenar, Hypothenar, Mid-palmar

DORSAL

Finger - Paronychia
Crease - DIP
- PIP
- MP

Dorsal phalanges - Distal
- Middle
- Proximal

Dorsum of hand

COMPLICATIONS - Osteitis, septic arthritis, Tenosynovitis, Spreading infection (cellulitis) Thrombophlebitis, Lymphangitis, Septicaemia; Extensive skin necrosis

Authors from the Infected Hand Clinic at the University College Hospital London (Pilcher et al 1948, Bailey 1952 and Bailey 1963) include the categories of subcuticular, intracutaneous and subcutaneous abscesses. Since the depth of the infection of the hand in relation to the skin and subcutaneous tissue is only a matter of degree, it is incorrect to regard them as separate categories.

Other writers (Loudon, Miniero and Scott 1948, Scott and Jones 1952) have attempted to assess the severity of hand infections by recording degrees of severity thus:

1st degree - No pus.
2nd degree - Pus localised and confined to one space.
3rd degree - Pus extended from original site to other tissues.
4th degree - Discharging sinus.

This method has obvious limitations for the whole hand may be very severely infected and yet pus absent (cellulitis) and conversely a localised infection with a sinus may be trivial. Clearly the presence of complications and the amount of tissue destruction are better indications of the severity of the infection, and this will be demonstrated in due course.

DISTRIBUTION OF HAND INFECTIONS

Grouped Sites

The distribution of hand infections by grouped sites is given in table XVI and the detailed distribution is illustrated in figs. 10 and 11. The main difference between the present investigation and other published series is that the site of infection is more evenly distributed over the hand. In particular, the distal volar pad (pulp) and paronychia of other

/series.....

Table XVI

Distribution of Hand Infections - Grouped Sites

Site	No. of cases
Volar	
Distal volar pad	157
Middle and proximal finger pad	100
Volar finger creases	187
Palmar pad and web	201
Thenar and hypothenar	33
Mid palmar	29
Dorsal	
Paronychia	44
MP, PIP, and DIP	175
Dorsal phalanges (excluding creases)	211
Dorsum of hand	58
Wrist	54
Other (multiple etc.)	29

series together make up about 50% of all hand infections (Pilcher et al 1948, Robins 1952, Scott and Jones 1952, Bailey 1952, Singer 1962) whereas the present 201 cases constitutes only 16% of the total. In the present series the various infections of the palm contribute a much larger proportion of the total.

Table XVII

Digit	Thumb	Index	Middle	Ring	Little
No. of infections	165	185	256	156	123

Right and Left Hands

Hand infections occurred on the right hand in 713 cases and the left hand in 564 cases, suggesting that the right hand is used more often than the left. This was confirmed when in 345 consecutive patients with hand infections it was determined

/that only.....

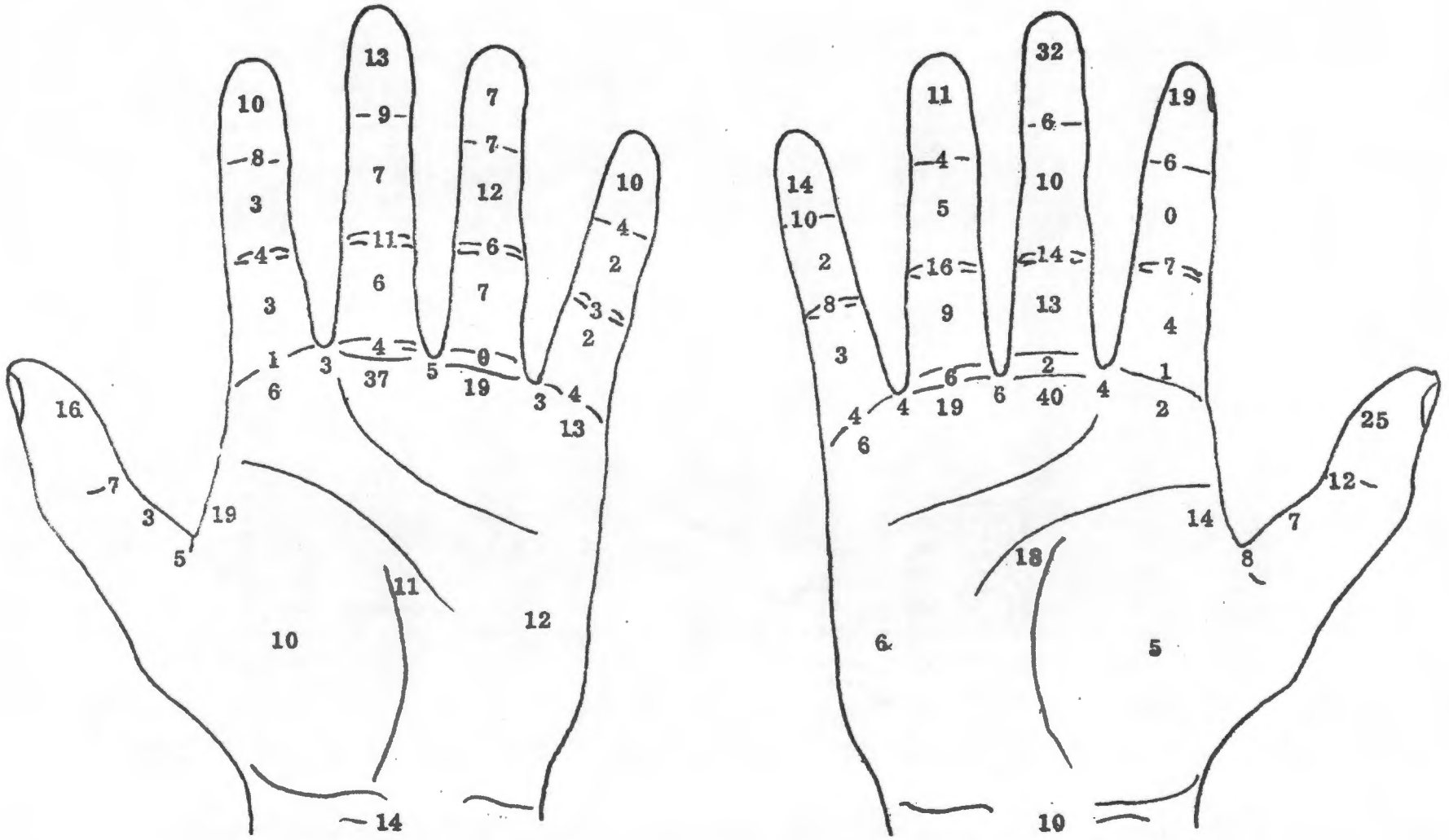


Fig. 10. Distribution of volar infections.

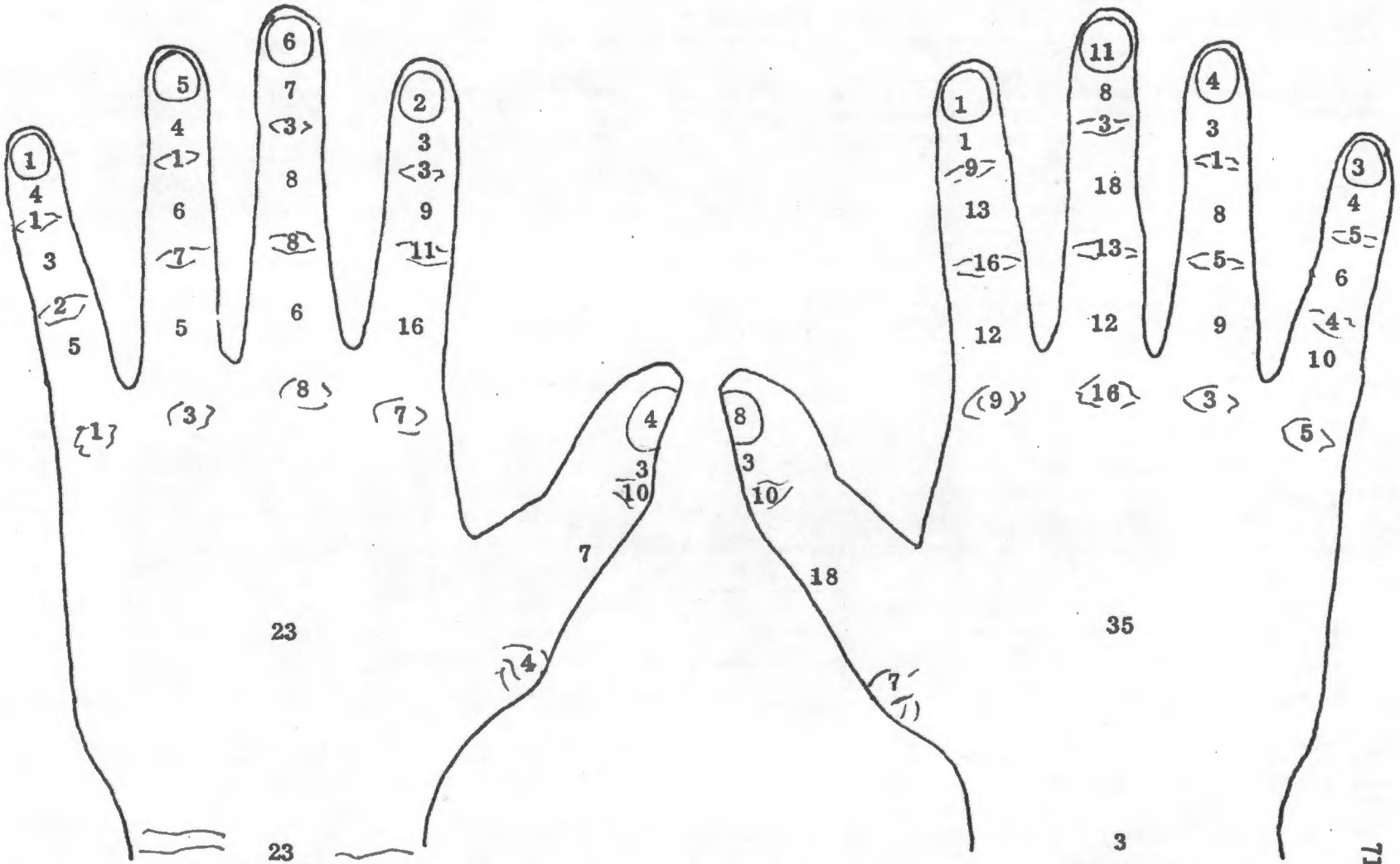


Fig. 11. Distribution of dorsal infections

that only 9 were left handed and the remainder were right handed. (This proportion of left-handedness is much lower than the 15% average quoted by Bunnell (1956).

Fingers and Thumb

The distribution of infections involving the fingers and thumb - dorsal and volar, is given in table XVII. (pg.69)

From figs. 10 and 11 it can be seen that infections are more evenly distributed in the left hand. Infections of the 1st webspace, thenar, hypothenar and 4th palmar pad (the pad at the base of the little finger) occur more frequently in the left hand. This is probably because of the friction caused by the sliding shaft of the spade or other implements in occupations such as lashing (shovelling).

The involvement of the right hand is especially heavy at the tips of the fingers and central palm on the volar aspect. Dorsally the right thumb, index and middle fingers are frequently involved. This may readily be explained on the basis of the more skilled tasks performed with the right hand, exposing these sites to be repeated trauma.

No adequate explanation can be given for the markedly higher incidence of infections on the dorsum of the wrist of the left hand, but it may be associated with friction at this site caused by protective gloves.

INFLAMMATION

Pathological Features

Inflammation has been defined as "the local reaction to injury of a living microcirculation and its associated tissues, including

/leucocytes.....

leucocytes and the perivascular cells such as mast cells and histiocytes". (Spector and Willoughby, 1963).

Once the organisms have entered the tissues, the establishment of clinical infection depends on a number of factors concerning host-pathogen interaction; these have been discussed in the previous section.

Howe (1954) in discussing wound infections with Staphylococcus aureus stated that it is probable that all surgical wounds are inoculated with bacteria at operation. A large number of industrial wounds are also contaminated at the time of injury (Williams and Miles 1949, Ellacombe 1963). The factors influencing the development of sepsis as enumerated by Howe are: the invasive capacity of the organisms; resistance of the host; size of inoculum; presence of physiological derangements; type of tissue involved; climatic or seasonal variations in bacterial flora and the staphylococcal carrier state in patients and personnel.

When the bacteria do gain a foothold, they multiply and release toxic substances through their metabolic activity. These toxins have a selective action on specialised cells of the patient, thus evoking their distinct clinical syndromes. Staphylococcal toxins cause tissue necrosis and thrombosis of vessels. Death of tissue is an early feature of staphylococcal infection and Pilcher and his co-workers (1948) noted that patients seldom report before it has occurred.

The inflammatory responses of the body tend to limit the local spread of bacteria. Because of local capillary changes

/there is.....

there is an outpouring of protein rich exudate which tends to dilute toxins and also forms a fibrin barrier against spread. Natural bacterial antibodies act on the bacteria and phagocytosis of the organisms by leucocytes takes place (Payling-Wright 1958).

As a consequence of the exudation of fluid and migration of cells at the site of inflammation, there is a local rise in pressure. This varies according to the site of the infection, for the distensibility of the tissues at different sites varies widely. In particular, a considerable increase in pressure may take place in the distal volar pad of the finger, which because of its anatomical structure cannot distend. Earlier writers, such as Handfield Jones (1946), thought that pressure alone was the cause of necrosis in infections of the distal phalanx.

The modern concept of inflammation is that it is an ever-changing process and that relatively soon after an injury the processes of breakdown and of reconstruction are to be found side by side.

The classical signs of inflammation, such as heat (more blood coming into the area), redness (dilatation of skin vessels), swelling and pain, are easily understood. The concomitant fever found with some forms is less easy to explain and the question of its pathogenesis has been reviewed (Atkins 1960). There are pyrogens to be found both in inflammatory exudates and in the circulation during experimentally produced fevers, but it seems that the only certain source so far identified, is the granulocyte.

The natural outcome of an inflammatory process is either resolution or the formation of pus. The latter is formed

/from.....

from living and dead leucocytes together with the exudate and autolysing tissue remnants, which together form the yellowish viscous fluid.

Reparative processes commence in the connective tissues once the acute inflammatory responses have settled. Fibroblasts proliferate and there are endothelial outgrowths from the capillaries, resulting in organisation by formation of granulation tissue. Intercellular fibres are laid down at a later stage.

Clinical Features of Inflammation of the Hand

Duration

The hand infections dealth with in this study are all acute infections and the length of time the patient has been aware of the presence of inflammation may generally be measured in days. Table XVIII illustrates the duration of infection before reporting, in the present series. The first symptoms noted are generally a feeling of itchiness and of local tension.

Murray (1951) and Claffey and Newton (1953) found that most patients presented after 3 days, i.e. from the 4th day onwards. Leaming Walder and Braithwaite (1960) found that the mean duration before reporting of patients coming directly to hospital was 6 - 9 days, compared to 2 - 5 days in patients referred by general practitioners. In their series of hand infections in Africans at Lagos, Hira and Lalljee (1964) found that the most frequent time before reporting was 4 - 7 days and they conclude that Africans do not delay before reporting as compared with Western nations.

In the present series the mean duration of infection before reporting was 4 days, which is slightly shorter than in

/other.....

other published series. The most frequent time before reporting was 2 - 5 days; on these days 746 patients reported (76% of 978 cases in which the time was recorded) - table XVIII.

Table XVIII

Duration of Infection before Reporting related to the Lost Shift rate and Complications

Duration of infection	No. of cases	Mean lost shifts	% With complications
1 Day	60	4.7	20.0
2 Days	175	5.1	15.4
3 Days	284	5.4	18.0
4 Days	174	5.9	21.8
5 Days	113	5.9	23.0
6 Days	46	6.8	30.4
7 Days	66	6.7	28.8
>7 Days	50	7.3	32.0
No record	310	-	-

Trauma as a Cause of Infections of the Hand

In section I it is shown that in 58% of recorded cases a history of injury was given or injury was apparent. It was also shown that repeated trauma is likely to be a contributory cause in the spread of infection from a follicle.

Inflammatory Fever

Constitutional symptoms are not a feature in most hand infections, but in the more extensive and severe infections e.g. large palmar abscesses, they may be present.

Evidence of Local Inflammatory Swelling

1. Pain The most important symptom in hand infections is undoubtedly pain. Saint (1949) states that pain is essentially due to the increased tension and that the severity depends on the rate of tissue destruction. Initially the pain is constant but

/soon.....

soon becomes throbbing with the formation of pus. It is worse at night and many writers have noted that pus is invariably present if the patient has spent a sleepless night because of pain. The pain is increased by dependency and reduced by elevation.

2. Swelling. The swelling in inflammation is due to vasodilatation, inflammatory exudate and accumulation of white cells, of which the second factor is the most important.

3. Impairment of function is due to pain, which is increased by movement and to swelling, which restricts movements.

Previous History

It is noted in Section I that hand infections are frequently preceded by infections elsewhere in the body or by other hand infections. In the present series 105 cases (8.1%) had previously been admitted to hospital for hand infections or other septic lesions.

Examination

General. Signs of toxaemia e.g. listlessness, apathy and flushed face are not frequent in hand infections; but a moderately raised temperature of up to 101 °F is not uncommonly encountered. Temperatures of up to 104 °F are recorded in rare cases of very severe hand infections and are usually an indication of lymphangitis or septicaemia.

Temperatures usually settle dramatically once the infection has been drained.

Local. Redness is not obvious in dark skinned people, but the other features of inflammation namely heat, tenderness and oedema are present to a greater or lesser extent. Fluctuation is a late feature in hand infections.

/Special.....

Special investigations. It is well known that leucocytosis occurs in acute pyogenic infections but as this would not influence the treatment in this series, blood counts were not made as a routine. Bacteriological studies, on the other hand, may be of considerable assistance in the management of cases.

MANAGEMENT OF HAND INFECTIONS

Surgical Drainage

The most important single factor in the management of hand infections is adequate surgical drainage. The removal or adequate drainage of a bacterial focus of infection will normally enable the defence mechanisms of the body to deal satisfactorily with the remaining bacteria.

Wilkie and other (1923) in a symposium on hand infections stated that for suppurative infection in tissue spaces or tendon sheaths prompt and free drainage was desirable.

In order to achieve effective drainage, an adequate anaesthetic and the provision of a bloodless field are most important, allowing the surgeon time for unhurried surgery and a clear view of the operating field.

In the present investigation 1,007 cases (79%) were operated upon. Of the remaining 271 cases, the majority (246 cases) were draining adequately when first seen and a smaller number (25 cases) resolved spontaneously.

Timing of Surgical Drainage

Timing of surgery is regarded as important by many writers, who stress that the infection should not be opened until it has "localised" (Handfield-Jones 1946, Bunnel 1956).

/Gordon (1950).....

Gordon (1950) often delayed incisions for some days while awaiting localisation, and Goldner (1962) holds that there is a safe waiting period. Most recent writers (Bailey 1963) tend to operate earlier and only delay surgery in early, diffuse, non-localised infections. One should certainly not wait for fluctuation to occur as this is a late feature in hand infections. The infection is generally ready for surgical drainage by the time the patient is first seen. In the earliest cases in which pus is not found, I have invariably found a plaque of necrotic tissue just below the skin, the removal of which accelerates healing. Pilcher and his co-workers (1948) noted that death of tissue is an early feature of staphylococcal infection and that patients seldom report before it has occurred.

Occasionally infections will resolve without resorting to surgery, but it is only experience that can guide one in this respect.

Hamlin (1961) disagreed with the aphorism "when in doubt drain". I cannot, however, recall a single case in which the hand infection was seriously aggravated by an incision performed too early, while my own experience and those of published articles all stress the ill-effects of delay.

Choice of Incision

Early writers evolved indirect incisions in an attempt to stop the spread of infections. Midline incisions were taboo as they were thought to result in tender scars and herniation of tendons (Iselin 1940). In current textbooks incisons vary from author to author, depending on their anatomical interpretations.

The most important general advance, brought about by

/the.....

the discovery of antibiotics, is the more direct approach to the inflammatory site. Hamlin (1961) noted that the only criteria of success of an incision to drain an abscess, are that it accomplishes its purpose, does not have to be repeated or revised and that the resultant scar subsequently interferes as little as possible with function.

The classical incisions of the earlier writers have been criticised by Gordon (1950) and the following points have been derived partly from his ideas.

(a) They provide indirect drainage.

(b) They often traverse first uninfected tissue, then the inflammatory barrier and finally the site of infection, thus encouraging spread.

(c) Damage may be caused to the very vessels and nerves that the incision was designed to preserve.

(d) The actual site of infection may be missed (particularly if the tendon sheath is involved).

(e) The evil ascribed to volar incisions is unwarranted.

Anderson (1954) noted that the classical incisions are often unnecessary, transgress the natural barriers of infection, do not drain well and leave an unsightly and tender scar.

Harrison and his co-workers (1949) were among the first to develop atraumatic technique and minimal incision. They made a small incision and excised slough and unhealthy subcutaneous tissue. This technique was modified by Anderson (1954), who described a deroofing method for some infections. Foreman (1960) supported this latter method and applied it also to subcutaneous collections of pus elsewhere in the body. The essential feature

/of de-roofing.....

of de-roofing is that a "circle" or "disc" of skin forming the roof of an abscess is removed in its full thickness and as widely as necessary to allow thorough cleansing of the abscess cavity. Entin (1964) agreed that when localised, the infection should be incised, the cavity washed out and necrotic elements excised. He felt however that the incision should be drained and the lips of the wound allowed to seal off with removal of the drain. Studying the significance of variations in surgical technique, English (1964) assessed 100 consecutive cases of hand infections of which 53 were saucerised and then given infrequent dressings and 47 were incised and drained by a wick of gauze and were given frequent wet dressings. He concluded that the need for re-operation, the period off work and the number of dressings required were less in the first group.

An excision-suture technique for infections of the hand has been described (Loudon, Miniero and Scott 1948, Scott 1952, Arden et al 1949, Murray 1951, Taranenko 1958). This method implies incision, excision of necrotic tissue when present, immediate suture of the wound and the administration of systemic penicillin. They conclude that this is the method of choice in well localised infection but that it should be avoided in diffuse infection and in some cases with sinuses. Its use is unnecessary in trivial infections. The results of this technique as judged by length of disability and the high failure rate, both in the literature and from my own experience, do not justify its use. Despite meticulous removal of pus and necrotic tissue, lesions invariably continue to drain for some time after surgery.

/Recommended.....

Recommended Surgical Drainage

In my opinion the method of choice is the deroofing technique which was used in all cases in this series. The least damage is done to normal tissues and the best drainage is provided by the circular hole that is cut in the skin over the centre of the abscess. The edges do not tend to fall together and prevent drainage as they do when a straight incision is made and so the use of rubber drains is eliminated. Though due care is obviously taken to preserve important structures, the necessity of elaborately planned incisions is obviated. The wound heals rapidly from the perimeter and leaves a minute scar. In fact no disability due to tender or adherent scars or loss of function as a result of surgical drainage, was encountered in any of the cases in the present series.

The deroofing method was used in infections of the volar and dorsal creases in the same way as elsewhere in the hand with the same good results. A tendon sheath may be explored or a joint opened, where indicated, through the same incision.

Subcuticular and Collar Stud Abscesses

True subcuticular abscesses simply require the snipping away of the cuticular layer without an anaesthetic. More frequently in this series, the subcuticular abscess has been the superficial component of a deeper 'collar stud' abscess. Where there is any doubt therefore, it is advisable to explore the abscess under tourniquet and anaesthesia, as the thin neck of a collar stud abscess invariably requires enlarging in order to allow for adequate drainage.

/Summary.....

Summary

The technique of deroofing over the maximal point of tenderness is advocated and has been used to a much greater extent in this series than in any other published work. After the removal of the 'disc' of skin, all underlying pus and dead and devitalised tissue is carefully removed.

THE USE OF ANTIBIOTICS

One of the most difficult and contentious problems in modern clinical practice is the use and abuse of antibiotics. The hope fostered at the dawn of the antibiotic era, that bacteria would cease to be an important menace to man's health has not been realised. Tough adaptable strains that frustrate attempts at control have emerged.

Even before the advent of antibiotics bacteriological studies were important as they gave the clinician a good idea of the course the disease was likely to follow. Bunnell's (1956) statement that it is not necessary to know the organism as long as the antibiotic sensitivity is known is therefore not supported. In fact the identification of the aetiological micro-organisms is ofter far more meaningful than sensitivity tests. (Jawetz 1963)

Bacteriology of Hand Infections

Earlier in this century, streptococci were an important cause of morbidity and mortality in infections of the hand. Koch (1934) reported on 32 cases of acute rapidly spreading infections of the hand following trivial injuries, in which there were 9 deaths. In 20 cases with bacteriological findings haemolytic streptococci were found in 10 and in 3 more were

/associated.....

associated with other organisms. Grinnel (1937) and Colonna (1940) found that streptococci were most frequently the cause of tenosynovitis. Some of the reasons for the recent decline of streptococcal infections are discussed in Section I.

More recently staphylococci have been found to be the predominant organism in hand infections. Bolton et al. (1949) isolated coagulase positive staphylococci from 99 out of 100 cases with pulp space infections. Anderson (1958) from 260 swabs isolated Staphylococcus aureus in 84.6% and Hira and Lalljee (1964) demonstrated staphylococci in 234 cases, or 74.5% of their series.

In the present investigation pus swabs were taken for culture and sensitivity tests from 434 unselected cases at the time of incision; and the results are given in table XIX.

Table XIX

Organisms Isolated from Hand Infections

Organism	No. of cases
Staphylococcus	415
Coliform organisms	10
Proteus	2
Streptococcus	2
Staphylococcus and Coliform	1
Staphylococcus and Streptococcus	1
Fungal overgrowth	1
No growth	2
Total	434

Antibiotic Sensitivity (general)

The discovery of penicillin revolutionized the management of severe staphylococcal infections; yet for some time the problem of the increasing prevalence of staphylococci resistant to antibiotics, has caused concern. Williams in 1959 stated that 30% of staphylococci in hospitals were resistent to

/antibiotics ..

antibiotics, compared to 7% of staphylococci outside hospitals. Buhr and Scott (1959) concluded that there has been a disturbing increase in penicillin resistant staphylococci in infections of the hand both in the general population and in the hospital community, but especially in the latter group. The emergence of resistant strains to virtually all antimicrobial agents which are used in large amounts in a closed environment has been observed (Bauer, Perry and Kirby 1950).

Gould (1958) noted that in a hospital environment, penicillin may accumulate and be redistributed through disturbance of dust and air and the handling of articles. Penicillin gains access to the nares of persons working in the hospital environment, thus inhibiting the growth of penicillin sensitive strains of Staphylococcus aureus while penicillin resistant strains become established. Carriers among the general population are not affected, because there is little chance of accumulation of penicillin or of cross-infection with resistant strains of staphylococci.

There are two types of resistance to penicillin in staphylococci, namely penicillinase and non-penicillinase types, the former being the only one of serious clinical importance (Knox and Smith 1961).

The control and even reversal of antibiotic resistance is of considerable importance and the separation of infected cases from clean cases and a policy of controlling the use of antibiotics in order to inhibit the emergence of drug-resistant staphylococci has been advocated (Barber and Burston 1955, Barber et al 1960, Jawetz 1963); Anderson (1958), however, observed that to deny the

/patient.....

patient the possible benefits of penicillin demands sound proof of its dispensibility.

Antibiotic Sensitivity (hand infections)

Because in modern civilian practice hand infections are most frequently related to industry and become infected outside the hospital environment it is not surprising that the majority of cases are sensitive to penicillin.

Results of some of the published reports on hand infections are as follows: Bolton et al (1947) in 100 pulp-space infections found 99 coagulase positive staphylococci and all were penicillin sensitive. Scott and Jones (1957), cited by Buhr and Scott (1959), found that 30% of staphylococci were resistant (having found no resistant strains in 1952). Anderson (1958) recorded that staphylococci were sensitive in 85% of cases. Hira and Lalljee (1946) recorded that 42.7% of their cases were resistant to penicillin.

Results of sensitivity tests in the present series are given in table XX.

Table XX

Staphylococcus - Sensitivity to Antibiotics

Antibiotic	No. Sensitive	% Sensitive
Penicillin G	343	82
Penbritin	355	85
Streptomycin	382	92
Tetracycline	392	94
Chloromycetin	59	14
Sigmamycin (oleandomycin & tetracycline)	413	99
Albamycin T (novobiocin and tetracycline)	417	100

(Total 417)

/While.....

While in the present series streptococci were sensitive to penicillin the coliforms and proteus organisms were insensitive to penicillin, but were sensitive to chloromycetin and albamycin T.

Local Antibiotic Applications

Antibiotics were initially used as local applications in hand infections. Some authors considered that the use of topical antibiotics was effective. Florey and Williams (1944) studied 212 cases of hand infections in 102 of which local applications of penicillin were used. They concluded that with the local penicillin the mean healing time was reduced, pain was relieved, the general condition improved and there was a more rapid return of mobility to infected parts. Grossmark and Plewes (1945) found local penicillin cream to be effective in whitlow, paronychia and webspace infection when the organism was sensitive, but that there was no apparent beneficial result on the end result in acute osteomyelitis of the phalanges.

Webster (1947) compared 260 unselected cases treated with adequate incision and removal of slough and local penicillin cream with 200 cases previously treated without penicillin and found that the length of disability was not appreciably shortened by this type of penicillin therapy.

Howes (1946) thought that broad-spectrum antibiotics seemed to give superior results in the local chemotherapy of wounds.

These writers all stressed that the antibiotic had to be given adequate access by removal of dead tissue.

Discussing the use of topical antibiotics in surgical infections, Lockwood (1947) stated that factors tending to delay

/or interfere.....

or interfere with wound repair, such as extensive tissue trauma, incomplete debridement, improper or ill advised closure with tension, residual dead space or implantation of foreign materials will always predispose to the development of infection in accidental wounds. The use of antibiotics in any combination and by any route does not prevent local infection of the wound when these predisposing factors exist.

The experience of the Americans of locally applied antibiotics during world war II (hand surgery in world war II 1955), did not confirm the early enthusiasm. They noted that sulphonamides, penicillin and later antibiotics all ran the gamut of acceptance and rejection in local application to open wounds.

The repeated injection and aspiration of antibiotics in furuncles and carbuncles has also been described (Meleney and Johnson 1953).

Though topical broad spectrum antibiotics are considered useful in the prevention of wound sepsis (Myles Gibson 1958, Wypkema 1965) it is generally accepted that they are not effective in the treatment of septic wounds, especially when slough and sequestra are present (Howes 1946). They have a place in the treatment of nasal carriers of staphylococci. (Stratford, Rubbo and Christie 1960).

Antibiotics Administered Systemically

Some time after the admission of sulphonamides into clinical practice, Beling and Abel (1940) optimistically reported that staphylococcal furuncles, carbuncles and abscesses treated with sulphonamides, disappear in less time than the shortest time required for an untreated lesion of the same kind. This claim

/has not.....

has not stood the test of time.

Writing at a time when penicillin was in short supply and had to be used by local application in order to conserve supplies, Florey and Williams (1944) felt that there could be little doubt that the best way of attacking the susceptible pyogenic organisms was systemically.

Even though penicillin is undoubtedly efficacious in the treatment of staphylococcal disease, its enthusiastic use in every case has given way to doubts whether it should be so universally used. Many writers have questioned the value of antibiotics in localised infections, and the place of antibiotics in hand infections is far from settled at the present time.

Antibiotics have been variously advocated before operation by some authors and after surgical drainage by others.

Curr (1945) stated that penicillin by intramuscular drip was successful in tenosynovitis and possibly septic arthritis and severe lymphangitis.

Pilcher et al. (1948) and Pilcher (1951) thought that antibiotics should be the first part of the treatment at whatever stage the infection is seen. Later Bailey (1952) from the same clinic noted that these ideas had been relaxed, penicillin being omitted in cases where the abscess was small and well localised. In paronychia penicillin was only used in about half the cases.

D'Abreu, Flood and Hewitt (1947) compared the results in 17 patients with paronychia, pulp infection, tenosynovitis or palmar-space infection, treated with penicillin, to those of 168 treated without penicillin. With the exception of palmar-space infection, there was a reduction in the time required for treatment

/and they.....

and they recommended that penicillin therapy should be routine in all severe infections of the hand, both in the early stages and after necessary surgical treatment.

Excellent results were reported with the use of penicillin in the treatment of infections involving bones and joints by McCorkie and his co-workers (1947). They also note that incomplete surgical removal of infected tissue is the most important cause of failure in penicillin therapy.

Bolton, Catchpole and Jepson (1947) investigated 100 consecutive cases with pulp infections. In 69 simple cases treated alternatively with and without penicillin, they found no significant difference in morbidity or complications, but destructive osteitis was eliminated in 20 cases of suspected bony felon treated with penicillin.

The literature concerning penicillin therapy in finger pulp infections was reviewed by Harrison, Topley and Lennard-Jones (1949) who concluded that the effect is not dramatic and can be obscured by other factors. They advocated that penicillin should be administered as a routine in all genuine cases of subcutaneous finger pulp infections.

Aird (1957) was of the opinion that penicillin administered in the treatment of carbuncles or boils, though doing little to hasten convalescence, has two beneficial effects. Firstly, oedema around the carbuncle is appreciably diminished and secondly, the incision may be undertaken as soon as there is a prospect of evacuating pus without any danger of causing a general spreading infection.

/Antibiotics.....

Antibiotics reduced neither the time of healing nor the number of visits required in soft tissue infections (Engelbrecht 1960, describing breast infections).

Three distinct uses for penicillin in hand infections are recognised by Robins (1952) namely, to abort an early infection, to localise and limit spread once suppuration has occurred and in severe infections involving bone, joint and tendon sheath. It is apparent that if these criteria are adopted almost all cases must receive penicillin.

Meleney and Johnson (1953) discussing the rational use of antibiotics in control of surgical infections, suggested the following criteria.

(a) The antibiotics obviate the necessity for surgery entirely.

(b) They permit a less extensive surgical procedure.

(c) They actually shorten the healing and recovery time.

(d) They permit a successful primary closure after removal of the focus of infection which otherwise would not be possible.

(e) They permit an earlier secondary closure than would otherwise be done.

In a study of 357 cases of sepsis of the hand in which three unselected groups received either no antibiotic, or oral penicillin or intramuscular penicillin, Anderson (1958) found respective healing times of 9.4, 9.5 and 9.2 days. He concluded that possibly web abscess or threatened infection of the structures that move and support the hand are the only firm indications for antibiotic therapy. It will not act as a cover for misdiagnosis

/or inappropriate.....

or inappropriate surgical measures.

Gordon (1950), Leaming et al. (1960) and Entin (1964) all use antibiotics extensively in all hand infections.

A more conservative approach is described by Plewes (1954), who states that no antibiotic is given in a localised infection when prompt surgical measures have removed the slough. Bacteriological studies of the tissue removed will indicate what antibiotic should be given 24 hours later if there is any evidence of spread of infection.

Bailey (1963), and most other authors at the present time, believe that antibiotic therapy is not required when treating small, well localised or superficial abscesses.

Whatever the indications for antibiotics, Jergensen and Jawetz (1963) in their study of pyogenic infection in orthopaedic surgery found that inadequate removal of infected or necrotic tissue could not be compensated for by adjunctive chemotherapy.

The Desirability of Restricting the Use of Antibiotics

The unnecessary use of antibiotics is to be condemned for several reasons:

1. The indiscriminate use of antibiotics has led to the emergence of antibiotic resistant strains of bacteria, especially of the highly adaptable staphylococci. This has already been discussed.
2. Antibiotics are not without their dangers and adverse effects may result from their use. Toxic and allergic reactions are not uncommon (Simon 1964).
3. Weinstein, Goldfield and Chang (1954) in a study of infections occurring during antibiotic therapy, noted that the administration

/of an.....

of an effective antibiotic agent to a patient with an infective condition, in addition to eliminating the causative organisms, produces a profound alteration in the composition of the bacterial population that normally inhabits certain tissues and organs. They noted that, though this by-product of antibiotic therapy is frequently of no clinical consequence, yet on occasion it is responsible for superinfection of a serious nature (usually with Gram-negative organisms) in addition to the one for which treatment was instituted. This has also been stressed by Jawetz (1964).

ANTIBIOTICS IN ABSCESSES - PILOT INVESTIGATION

In 1961 I carried out a pilot survey of all types of boils and abscesses, including hand infections, admitted to the Ernest Oppenheimer Hospital. One of the purposes was to assess the place and value of antibiotics in the treatment of these cases. Patients in the septic wards had previously been given antibiotics irrespective of the nature, site or extent of the infection. Moreover the majority of minor wounds and infections treated at the dressing stations were given penicillin there.

Results of this investigation are given despite their possible shortcomings, since the subsequent management of cases was based partly on these findings.

A total of 472 consecutive cases of a variety of septic lesions were treated alternately with and without antibiotics. Patients receiving antibiotics were given injections of 600,000 units of procaine penicillin twice daily until the infection cleared. Other aspects of treatment were the same for both groups.

Cases in which complications developed are analysed

/separately.....

separately; of the remainder, 215 were treated with antibiotics and 226 without antibiotics. The average stay in hospital for these groups was 4.3 and 4.2 days respectively.

Complications in patients treated with antibiotics (14 cases)

Allergic rash (1 case)

Tendons exposed requiring grafting (2 cases)

Prolonged healing (11 cases)

Complications in patients treated without antibiotics (17 cases)

Spread of infection (2 cases)

Septic arthritis (1 case)

Tenosynovitis (1 case)

Prolonged healing (13 cases)

The conclusions of this pilot investigation were that soft tissue infections, if adequately drained, did not benefit from the administration of antibiotics. Preventable complications usually resulted from mistakes in diagnosis and inadequate surgical treatment and occurred whether antibiotics were given or not.

After the pilot investigation, all antibiotics were withdrawn from the mine dressing stations and their use in the septic wards was restricted. This action led to no apparent ill effects.

Proposed Indications for Antibiotics in Hand Infections

From the preceding discussion, it is apparent that antibiotics have contributed in no small measure to the management of hand infections, though the indications for their use are ill defined. It has also been suggested that their routine use in

/every.....

every case is not only unnecessary, but also undesirable. The aim should therefore be to administer antibiotics to cases in which they are likely to significantly reduce the time of treatment and subsequent disability, but to restrict their use in other cases.

The indications for the use of antibiotics which I propose are (a) infections of tissues which respond poorly to infection, namely bones, joints and tendon sheaths and (b) cases where body defences are inadequate and the infection is spreading, as manifested by cellulitis, thrombophlebitis and septicaemia.

There are several other situations in which most clinicians dealing with hand infections would almost certainly give antibiotics; these are as follows:

Lymphangitis. Streptococcal lymphangitis was frequently encountered earlier in this century but nowadays streptococcal hand infections are rarely seen. In the African, the inflamed lymphatic vessels leading to lymph nodes are not visible owing to their dark skin. Lymphatic spread is evidenced by enlarged and tender epitrochlear and axillary lymph nodes. In this series of 100 consecutive cases of hand infections undergoing surgical operation on the day of admission, in 80 cases there was no evidence of lymphatic spread, while regional lymph nodes (epitrochlear and/or axillary) were involved in 20 cases. Antibiotics have not been administered in this series simply because of lymph node involvement, for I have found that it subsides readily on local drainage and supportive treatment. In no instance did the epitrochlear or axillary lymph nodes suppurate or require drainage.

Pyrexia and other toxic manifestations. In acute osteomylitis of children, Louw (1965) noted that pyrexia and other

/toxic.....

toxic manifestations were not cured by the administration of antibiotics, but would settle down when the pus was drained. The same applies to hand infections, in which the use of antibiotics simply because the patient is pyrexial is not advocated.

Oedema. The presence of oedema which is especially marked on the dorsum of the hand, is not in itself an indication for antibiotics. It must however be distinguished from cellulitis or spreading infection.

Extensive infections. Except where the infection is spreading or some other complication is present, the extent of the infection has not been a consideration in the administration of antibiotics in this series.

Tissue necrosis and extensive skin loss. Where extensive tissue necrosis and extensive skin loss has occurred and the necrotic tissue is adequately removed without evidence of complications or spread of infection, antibiotics have not been administered.

Administration of antibiotics to abort early infections. One of the main hopes following the introduction of antibiotics was that infections seen at an early stage might be aborted and the patient saved from having to undergo surgery.

Schneewind (1960) thought that because of the introduction of antibiotics the number of cases with hand infection declined but now appear to be increasing, possibly owing to an increase in resistant organisms. These views are certainly not confirmed by a review of the literature.

/Robins (1952).....

Robins (1952) believed that penicillin could abort early infection, but noted that since general practitioners see most uses with early infections no satisfactory estimate of this could be made.

Webster (1947) reported that in 7 cases seen early enough for an attempt to cause the infection to abort by the administration of parenteral penicillin, this was only successful in 3.

In Wypkema's series (1965) only 3 pulp space infections aborted and in 8% the use of antibiotics unduly delayed surgical treatment and prolonged convalescence.

I have had the opportunity of seeing patients at the very earliest stages of hand infections and have found that some of these will clear up spontaneously by simply removing the man from his work and resting his hand. In 25 of the present series (2%) the infection resolved spontaneously without the administration of antibiotics. I have also observed that in some cases hand infections have actually commenced while the patient was receiving antibiotics.

For these reasons one cannot recommend that antibiotics should be used in early abscesses in an attempt to abort the infection.

Choice of the Antibiotics

According to Jawetz (1964) the selection of the correct antimicrobial drug should be based firstly on experience and secondly on the results of bacteriological testing.

Entin (1964) recommended the initial use of an antibiotic that has a wide spectrum but very low toxicity.

/Other.....

Other authorities have stated that in spite of the impressive developments and the promise of more to come, no antimicrobial agent yet discovered or synthesised, can match penicillin G for safety, overall efficacy and economy (Simon 1964, Smith 1964).

Where the organism is insensitive to penicillin, Smith (1964) advocated the use of erythromycin, oleadomycin and novobiocin in less serious infections. Because of the emergence of resistant strains, the newer penicillins should probably be reserved for the most seriously ill patients (Simon 1964).

Antibiotic combinations have been advocated by Jawetz (1963) and their use has been supported on genetic grounds to prevent the emergence of antibiotic resistant mutations (Tatum 1959). Garrod (1965), however, feels that combinations should only be used in a few specific instances and that the proper place of combinations in therapeutics is otherwise doubtful.

Where antibiotics were indicated in the present investigation penicillin (either aqueous penicillin 1,000,000 u. initially followed by 500,000 u. 6 hourly or procaine penicillin 6000,000 u. twice daily) was commenced. Failure to respond or bacteriological insensitivity could indicate a change of antibiotic. Occasionally, in severe infections, broad-spectrum antibiotics were used from the outset. From local bacteriological results and experience, the broad spectrum cover that I favour is a combination of Novobiocin and Tetracycline (Albamycin T). In the present study the only antibiotics used were penicillin and Albamycin T.

/Analysis.....

Analysis of cases treated with antibiotics

In the present investigation 291 cases (22.8%) received antibiotics and 987 cases (77.2%) were managed without antibiotics.

An analysis of the indications for the administration of antibiotics is given in table XXI, from which it will be seen that only 23% of the patients in this series received

Table XXI

Indications for the Administration of Antibiotics

Indications	No. of cases
Complications (excluding cellulitis)	196
Spreading infection (cellulitis)	46
Suspected complications	29
No reason ⁎	20
Total	291

⁎ Patients who on admission to the wards had inadvertently been started on antibiotics and were therefore continued.

antibiotics (or 21% if the 20 cases are excluded that received antibiotics for 'no reason' by the criteria adopted).

Considering that the majority of these infections would have been classified as serious by other writers, this is by far the most conservative use of antibiotics reported in the treatment of hand infections.

Penicillin was used in 280 cases (of which 16 subsequently were given broad spectrum antibiotics) and broad antibiotics only were used in 11 cases.

GENERAL SUPPORTIVE MEASURES

Rest and Movements

There is general agreement that the hand should be rested initially to help localise the infection. Rest relieves pain and also aids the lymphatic system, which functions more efficiently when the rate of flow of incoming lymph is diminished (Payling Wright 1958).

Iselin (1940) continued immobilisation until healing was complete but later the tendency was in favour of earlier post operative mobilisation (Handfiled-Jones 1946). Bailey (1963) initially immobilises the hand in a plaster-of-Paris splint but encourages early movement.

The hand is rested during the stage of acute inflammation. Early active movements are encouraged soon after surgery and during the recovery stage. Movements are naturally limited by pain.

Splints or bulky dressings are not used except for aluminium splints for MP ro PIP joints, and the hand is allowed to rest in a comfortable, natural position.

The major causes of residual stiffness of the injured hand is in and about the joints and prevention of stiff joints by early movement is the most practical solution to this common problem (McCormack 1964).

Physiotherapy may accomplish much during the stage of recovery (van Niekerk 1965).

Oedema of the Hand

An essential part of the inflammatory process is the outpouring of protein rich exudate into the tissues. Because of the laxity of its tissues the dorsum of the hand often balloons

/out.....

out markedly (fig 12). Oedema is frequently seen in infections of the palm, and writers often warn the unwary that the apparent fluctuation is rarely the sign of pus. The actual inflammation is situated elsewhere and is usually obvious when looked for (fig 19, page 120).

Barclay (1964) defined the causes of oedema of the hand as infection, trauma and disuse in dependency.

The effects of persistent oedema and prolonged immobilisation have been discussed by Bunnell (1956). "Joint ligaments are just long enough, and if from any cause a hand remains swollen and immobile, the serum soaked ligaments become short and thick, binding the joint. From the fluid of oedema, fibrin settles between the movable tissues and within the muscles, tendons and joints alike. Fibroblasts invade and the whole becomes organised and shrinks and a congealed hand results".

Elevation and rest are the most effective means of treating the inflammatory oedema (fig 13). A pillow laid next to the patient with his hand placed on top of it serves no useful purpose. In most other units, where hand infections are treated on an out-patient basis, oedema is managed by the use of a broad arm sling, with the hand lying in front of the opposite shoulder (Bailey 1963).

The status of anti-inflammatory enzymes is not established at present (Barclay 1964). Calnan and Barr (1960), Gall and Tallbot (1962) and Wypkema (1965) did not find them to be of use, but others believe that they are effective (Moore 1959, Thorek and Panchit 1964). I have not found that persistent oedema is a problem in hand infections. The swelling

/usually.....

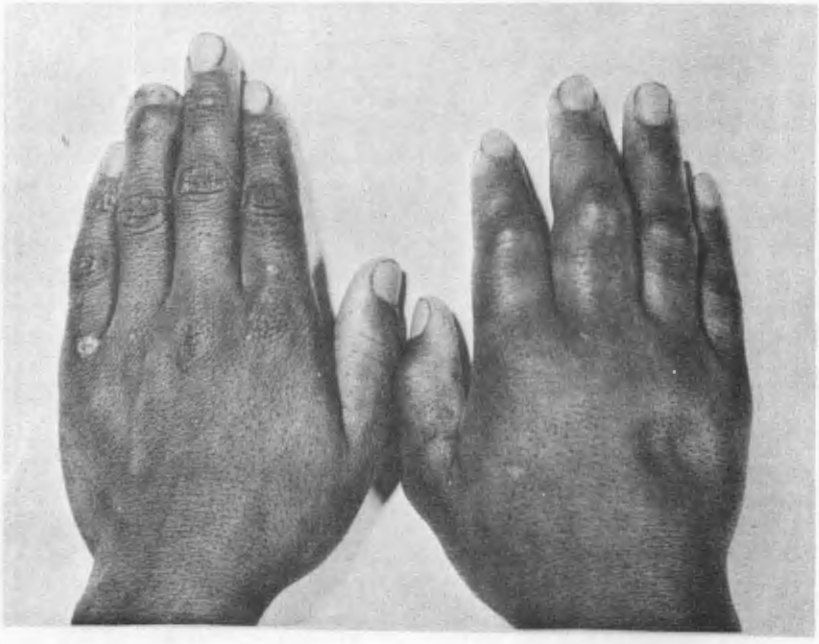


Fig. 12. Dorsal oedema.
The actual infection was situated at the palmar pad of the middle finger (See fig.19).

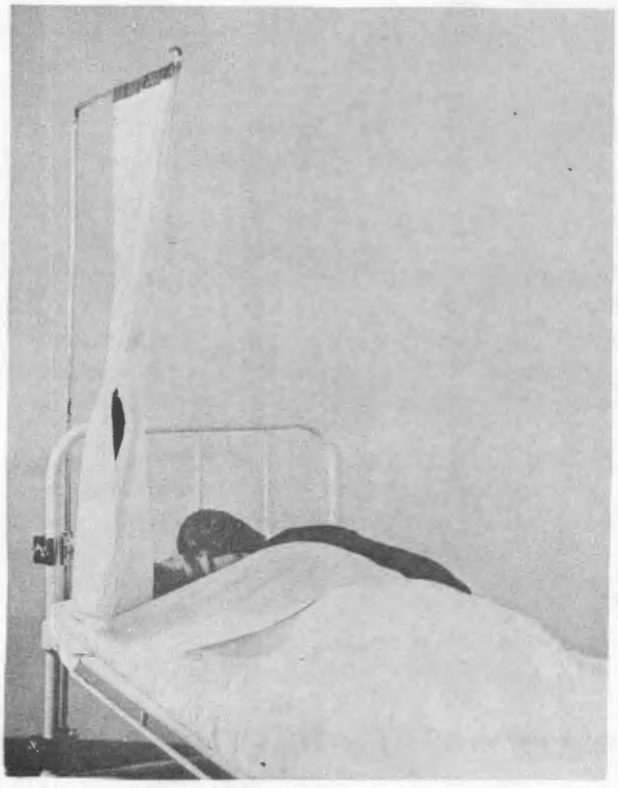


Fig. 13. Method of elevating hand.

usually settles in a day or two after adequate drainage and general supportive measures, and therefore no patients in this series were given proteolytic enzymes.

Oedema is such a striking feature in many cases of hand infection that an attempt was made to evaluate it in the present investigation. Where swelling was absent or confined to the actual inflammatory site it was described as 'nil or slight'; more extensive oedema, but confined to a finger or part of the hand, was described as 'localised' and oedema of the whole hand was described as 'generalised'. These details were recorded in 916 consecutive cases of infections of the hand. The results are shown in table XXII. (Further details concerning oedema and its relation to lost shifts will be found in this section under the heading 'Results of hand infections').

Table XXII

Oedema of the Hand

Degree of oedema	No. of cases
Nil or slight	298
Localised	321
Generalised	297
Total	916

Dressings

Elaborate routines of wet dressings and hot or cold packs were extensively used by all the earlier writers including Kanavel (1940) and Iselin (1940). Handfield-Jones (1946) was one of the first to dispense with these dressings, noting that they macerated the skin, encouraging further infection and

/delaying.....

delaying healing. Most recent writers no longer use wet dressings, though they are still used by a few (Goldner 1962), Hamlin (1961) even stated that if only one method of treatment was allowed, the hot pack would be preferable to antibiotics in dealing with infections of the hand.

Colebrook and Hood (1948) demonstrated that wound pathogens can grow through an intact dressing when this becomes soaked with exudates and suggested that some of the cases of cross-infection of open wounds in hospitals might arise in this way.

I have used simple dry gauze dressings, and where these may cause pain by becoming adherent, a thin layer of vaseline gauze or 'Sofra tulle' (paraffin gauze impregnated with 1% framycetin sulphate) is used for the first few days.

Other applications e.g. furacin (Shipley 1947) may also be used. Some writers have advocated frequent changes of dressings, while others have urged that they should be kept on for a few days. I feel that the timing of dressings is largely academic, but have found it useful in most cases to inspect the wounds daily in the acute stages. Dressings should obviously be changed more frequently when there is a profuse discharge and less frequently while awaiting healing.

The wound and surrounding skin is kept clean by washing gently with dilute antiseptic solution and removing dead epithelium.

Miscellaneous Aspects of Treatment

Staphylococcal Serum and Toxoid

Though staphylococcal antitoxic serum has been reported as being of definite therapeutic value in toxaemic states

/by many.....

by many investigators, it has nevertheless come to be neglected in the antibiotic era, except in Europe. It is said to be useful in acute spreading infections, generalised sepsis and severe toxaemia but not in local or chronic lesions. Other continental contributors also support active immunisation with toxoid for treatment of chronic and soft tissue infections (Mudd 1962).

Radiation

X-rays are a method of treatment of infections that was tried and said to be of use in the pre-antibiotic era (Smith and Manges 1937) and has also been reported on more recently by continental workers (Stukova 1958).

Passive hyperaemia

Passive hyperaemia (Biers hyperaemia) by means of a partially occlusive cuff applied to the upper limb was used occasionally before the advent of antibiotics in an attempt to keep infections localised (Wilkie 1938) but soon fell into disrepute.

SPECIFIC INFECTIONS

DISTAL VOLAR PAD (PULP) INFECTIONS

In this group all infections from the distal volar crease round to the distal and lateral edges of the nail are included. Though one of the commonest variety of acute hand infections in the literature, distal volar pad infections (157 cases) comprise only 12.3% of the present series.

Pilcher and his co-workers (1948) Bailey, (1952, 1963) and Parsons (1962) distinguish 'apical' infections which occur

/distally.....

distally just under the edge of the nail from other pulp infections on the basis that the former are less liable to develop osteitis.

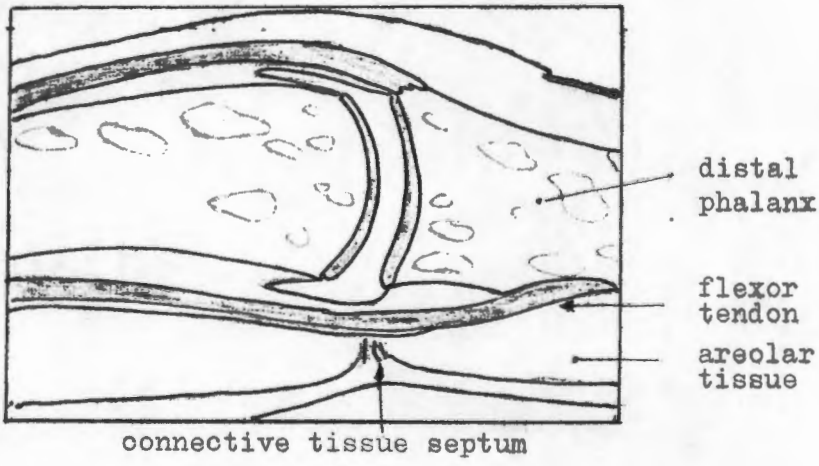
These two entities have not been differentiated in this series, because they are essentially infections in the same anatomical structure and there is a considerable overlap between the two conditions.

Anatomical and Pathological Features

The distal volar pad consists of a collection of fat lying in the interstices of a fibrous net which has dense strands attaching the deep surface of the epidermis firmly to the periosteum of approximately the distal 2/3rds of the distal phalanx (Pilcher et al. 1948, Bunnell 1956). Of the volar

Fig. 14

Anatomy of the distal volar pad at the insertion of the flexor tendon (after Wilkinson)



aspect of the distal phalanx the proximal portion is occupied by the flexor tendon insertion, which extends well beyond the base of the phalanx, though the cavity of the synovial sheath terminates immediately distal to the junction of the proximal septum of the pulp space (Wilkinson 1950 - 51) - fig 14.

/Though.....

Though the distal phalanx is supplied with a rich anastomotic blood supply the availability of adequate collaterals is reduced sharply as one passes distally from the hand to the digits (Edwards 1960, Flint and Harrison 1965).

Earlier writers held that infection and necrosis of the distal phalanx resulted from pressure on two digital vessels that traverse the pulp. The frequent survival of the proximal portion of the distal phalanx was thought to be due to its receiving a separate blood supply which does not traverse the pulp (Klapp 1923, Handfield-Jones 1946). Other authors attributed the necrosis solely to the staphylococcal toxin (Pilcher et al. 1948).

In my opinion the inflammatory process is aggravated by (1) the increased pressure caused by the unyielding nature of the fibrous septa, which are attached to bone and skin, (2) the inability of inflammatory fluid to escape due to Clelands ligaments, the firmly fixed nail and the connective tissue septum of the distal volar crease, (3) the relatively poorer blood supply of the distal portion of the finger.

I agree with Farquharson (1962) that bone is involved by direct spread (see fig 21, page). This may be readily demonstrated at operation and on X-ray. It may be seen that when bone is involved, this is at first closely related to the site of the infection. Where necrosis is extensive, I have observed that this is often due to the stripping of the periosteum by the inflammatory process, thus cutting off the blood supply of the underlying bone.

The blood supply of the proximal part of the distal phalanx is maintained through the periosteum which is united

/particularly.....

particularly strongly over the attachments of tendons and ligaments by Sharpeys fibres (Last 1959), and from the freely anastomosing blood supply of the fibrous capsule of the joint (Barnett, Davies and MacConnaill 1961).

Extension or Spread

Extension or spread of the infection from the distal volar pad may follow several routes. Most frequently the infection spreads to the underlying bone. Sometimes the infection tracks dorsally and laterally presenting at the side or corner of the nail as a paronychia; this generally has no special significance except that the unwary may make a mistaken diagnosis and fail to drain the infection adequately. Less frequently the tendon sheath, joint or rest of the finger (as a cellulitis) may be affected.

Extensive soft tissue necrosis of the distal phalanx with loss of skin may also occur.

Clinical Features

The patient complains of a throbbing pain and at first only a slight fullness of the distal volar pad is noted, though Koch (1929) was of the opinion that board-like distension is an early feature.

Even at this stage a point of maximal tenderness can usually be elicited and this should be explored as pus is invariably present.

A discharging sinus or a drumstick finger (Aird 1957) are late signs of infection and complications are frequently present.

/Surgical.....

Surgical Drainage

The 'alligator' or 'fish mouth' incisions and subsequently 'hockey stick' incisions of earlier writers (Lake 1938, Kanavel 1940) are still frequently recommended (Bunnell 1956, Furlong 1957, Marble 1960, Entin 1964) while lateral through and through incisions cutting all the septa are also used (Farquharson 1962, Milford 1963, Boyes 1964). The inadvisability of using these classical incisions has already been discussed.

I have used the method as described by Anderson (1954) of a deroofing incision directly over the abscess (see fig 15) while other authors (Bailey 1963) advocate the use of an elliptical incision.

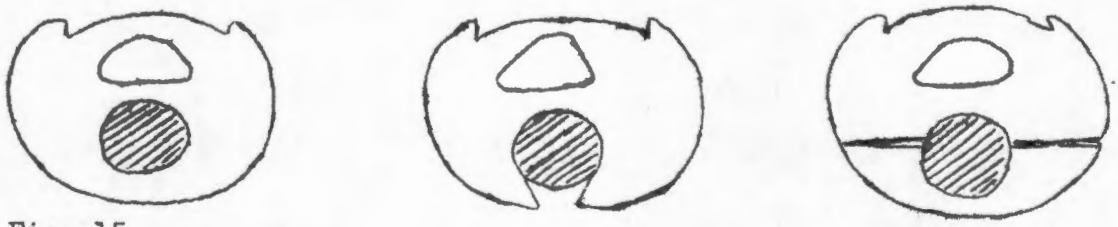


Fig. 15

(a) Distal volar pad abscess (b) Deroofing incision (c) Classical incision

Through the deroofing incision, pus and necrotic material are removed and the distal phalanx is inspected and probed. The characteristic grating feel of bare bone indicates bony involvement.

PROXIMAL AND MIDDLE VOLAR PAD INFECTIONS

Infection of the proximal and middle volar pads differs from that of the distal volar pad in that they have no fibrous septa to build up pressure. Spread of infection is limited by the volar creases and by Clelands ligaments situated just dorsal to the neurovascular bundles.

/Because.....

Because of the close proximity to the tendon sheath, infection may spread to the sheath and this should be borne in mind when exploring a lesion.

Surgical drainage is effected by the method that has been discussed i.e. deroofing incision and removal of pus and slough.

INFECTIONS OF THE VOLAR FINGER CREASES

Infections occurring at the volar finger creases have not previously been specifically described, although attention has been drawn to the danger of puncture wounds at these sites because of the proximity of the tendon sheath.

Because of their frequency (197 cases or 14.6% of the total in the series) and clinical features, with their special tendency to cause tendon sheath infection, I believe that they should be regarded as a separate entity.

Cause

Puncture wounds or scratches were seldom the cause of infections at the volar finger creases in the present investigation. Most frequently the infection resulted from a blister at the crease and often the cause could not be determined. These cases would fall into the 'beat' category described by Collis and Llewellyn (1924).

Presentation

Infection at the creases frequently presents as a collar-stud abscess with a subcuticular and a deeper component. The abscess often 'saddles' the crease with proximal and distal extensions.

/Surgical.....

Surgical management

Incisions across the finger creases are generally regarded as undesirable (Singer 1962).

I use the deroofing technique as with all other infections and though this crosses the flexor crease, no disability due to the incision has occurred in any of the patients. Drainage is once more most effective, the patient is capable of early movement with minimal discomfort and his return to work is in fact facilitated.

I make a practice of visualising the tendon sheath; this aspect is discussed in the chapter on "the complications of hand infections".

INFECTIONS AROUND THE NAIL (PARONYCHIA)

Subcuticular abscess of the nail fold, or paronychia is the commonest acute infection of the hand reported in the literature, accounting for about 30% of all septic lesions of the hand and fingers. In the present study they occurred much less frequently, the 44 cases accounting for only 3.4% of the total.

These infections are subcuticular, being situated within the epidermis (Pilcher et al. 1948). They may lie on the superficial or deep aspect of the nail fold and may extend round the fold or under the nail to a varying extent.

They are usually classified as 'acute' when they have been present for less than 14 days and 'chronic' when longer (Bailey 1963). Apart from recognising the implications of any infection of the hand which has been present for a long time (see chapter on delayed reporting), I regard this distinction as academic and do not distinguish between the two. The

/recognition.....

recognition of a separate entity such as a chronic paronychia caused by a fungal infection is another matter.

Management

The classical methods of drainage for paronychia showed lack of appreciation of the pathological changes. The base or the whole nail was removed despite minimal involvement and lateral incisions were made in the nail fold (Iselin 1940) - see fig. 16.

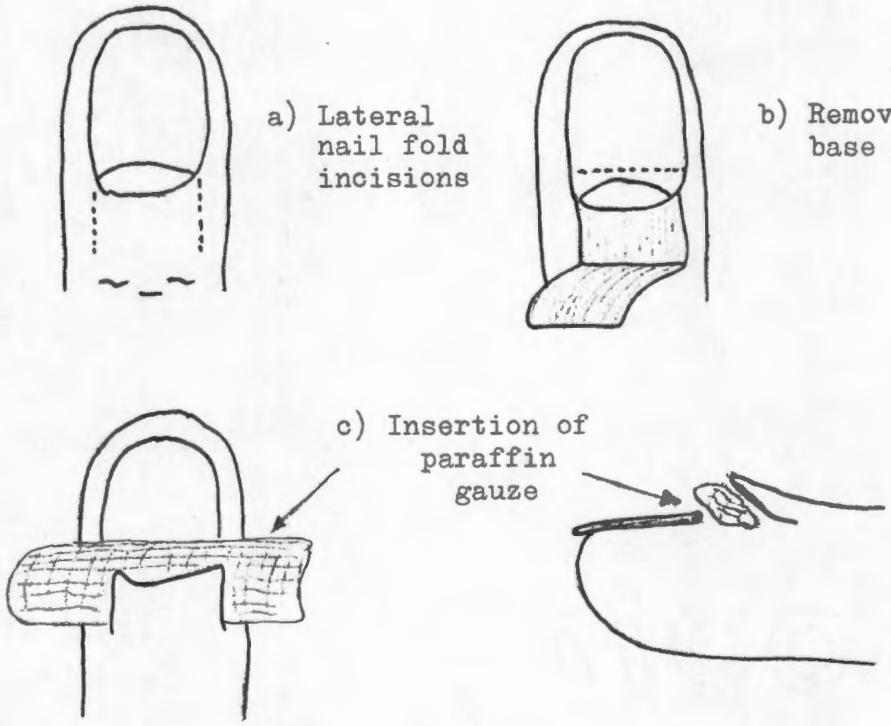


FIG. 16 The classical method of drainage for paronychia

These ideas have been perpetuated in many modern textbooks (Marble 1960, Furlong 1957, Farquharson 1962, Milford 1963, Boyes 1964).

Macey (1940) advised conservative treatment with moist soaks and X-ray and surgical treatment only if this failed.

Where the subcuticular component is not hidden by the

/nail.....

nail fold, it may be possible to snip this away painlessly and effectively. More often an anaesthetic and bloodless field are needed and should be employed. The eponychium or fold of cuticle

FIG. 17 Paronychia before (a) and after (b) drainage

adhering to the base of the nail is gently pushed back with a blunt probe towards the base on the affected side of the nail. This manoeuvre usually liberates pus. Loose cuticle is excised and the cavity cleared. (Fig. 17)

Where the infection has spread under only part of the nail, Foreman (1950) advocates removal of the whole nail. I remove the affected portion only. The residual nail fulfils its function of giving firmness to the distal volar pad and because of the localised nature of the drainage, the patient has less discomfort and is able to return to his work at an early stage. I have not found that the old nail interferes unduly with the new nail growth as stated by Anderson (1956), who advocated a more radical approach. Anderson excised a wedge of nail fold if there was spread under the base of the nail, but this has been found to be unnecessary. Where the whole nail is 'floating' it should be removed (Fig. 18).

/Complications.....

Complications

Complications do not often occur, because of the subcuticular nature of the infection, though osteitis and septic arthritis of the distal phalanx and distal interphalangeal joint may develop in some cases.

INFECTIONS OF THE WRIST AND DORSUM OF THE HAND AND FINGERS (EXCLUDING CREASES)

Infections of the wrist, dorsum of the hand and fingers are considered together, as they present similarly and are treated in the same way.

The management varies slightly depending on whether the infection is of the clinical type 'abscess', 'boil' or 'carbuncle' (Aird 1957). In some cases the main feature is pus formation with little or no 'pointing' or 'head' while in others the main feature is skin necrosis and slough formation. The infection frequently arises in a hair follicle or sebaceous gland and may spread to adjacent hair follicles and the subcutaneous tissue, when a 'carbuncle' is formed.

The dorsum differs from the volar aspect of the hand in that there are no creases or fibrous tissue barriers to limit the tracking of pus in the tissue plaines and the infection may spread proximally up a finger, or extend widely over the dorsum of the hand. This, however, does not constitute a 'cellulitis'.

Surgical drainage

In the 'abscess' type of infection, the pus is drained by the deroofing method. Deroofing may sometimes be necessary at more than one site because of the tracking of pus.

/Opinions.....

18 (a)

18 (b)

Fig. 18 a & b : Removal of ' floating' nail.
(This also illustrates the superficial nature of a paronychia - this nail was removed painlessly without an anaesthetic).

Opinions have varied as to the best management of carbuncles though most authors advocate a conservative approach. Anderson (1954) stated that with the exception of paronychia nearly all infective lesions on the dorsum of the hand and fingers are carbuncles and that incision has no place in their treatment. Pilcher (1951) held that incisions were not necessary in most cases, while Robins (1952) treated his patients by initial immobilisation, penicillin and hypertonic saline and reserved incision for cases with subcutaneous pus pocketing. Entin (1964) incises only if an indolent necrotic core persists after treatment with local heat, immobilisation, rest and elevation. He does not use cruciate incisions, but prefers straight incisions and a sweeping incision in a plane parallel to the skin in order to evacuate all loculations. In addition to a stellate incision reaching as far as the borders of the induration, Bunnel (1956) recommended that each flap should be undermined to cut the vertical columns.

I have found that spontaneous separation of slough takes many days (this is supported by the long periods of disability with carbuncles of the hand cited by most authors) and that the spread of infection is facilitated because of poor drainage. Removal of the slough considerably speeds recovery. I do not practice extensive or cruciate incisions, but simply remove the slough and devitalised tissue (often firmly adherent); underlying pus is usually present and is drained. Tracks of slough often extend radially to adjacent hair follicles and these are conveniently removed with a mosquito forceps.

/The.....

The indications for antibiotics as discussed previously seldom apply and patients in this group rarely received antibiotics.

Surgery is not necessary where the infection is draining adequately.

Complications

Complications occur rarely in the dorsum of the hand and wrist, but more commonly in the distal phalanges. Infection of the dorsum of the distal phalanx are most liable to complications because of the relatively poor blood supply and the increase in pressure (inflammatory exudate cannot readily escape because of the fixed nail distally and Clelands ligaments laterally). Osteitis of the distal phalanx or septic arthritis of the distal interphalangeal joint may result from infections at this site.

INFECTION OF THE DORSAL FINGER CREASES

Infections of the dorsal finger creases may arise from superficial abrasions or, like other dorsal infections, from no apparent cause. However, the vulnerability, especially of the MP and PIP joints, to puncture wounds penetrating the joints, has already been discussed. The danger in these cases is the possibility that a septic arthritis may develop.

My approach to infections of the MP, PIP, or DIP creases is to use the usual deroofing incision, with removal of pus and slough. Where a septic arthritis is clinically suspected, the joint is aspirated through the same incision and drained if the diagnosis is confirmed by the presence of turbid fluid.

/Infections.....

INFECTIONS OF THE PALM OF THE HAND

I have classified infections of the palm of the hand as infections of the web, palmar pad (at the base of the fingers), thenar, hypothemar and mid palmar infections.

The particular interest of Kanavel (1940) was his study of various palmar spaces and potential paths in the hand of spread of infection, which he defined by the injection of radio-opaque material and dissection.

Jamieson (1950) studied the anatomy of the fascial spaces of the palm by dissection and reviewed the literature. He showed that the hypothenar and thenar spaces are not fascial spaces at all, but merely intervals separating the intrinsic muscles of the little finger and thumb from the palmar aponeurosis. He described 2 main spaces - the mid palmar and adductor spaces. In addition to its attachement to the palmaris longus tendon, the palmar aponeurosis has deeper fibres that are continuous proximally with the distal border of the flexor retinaculum, end at the level of the superficial transverse ligament with decussations in the centre of the palm, and are absent over the thenar and hypothenar parts of the aponeurosis. The aponeurosis is firmly attached to the bony framework of the hand. A particularly strong group of fibres from the 3rd metacarpal (in common with the adductor transversu pollicis) forms the oblique septum which divides the palm into the mid-palmar laterally and adductor space medially. The index tendons and their coverings are situated in the lateral extremity of the septum from their emergence from the carpal tunnel to their entry into the fibrous sheaths of the fingers.

/Birks.....

Birks (1945) described infections of the superficial palmar space in which a collection of pus behaves as though it was confined between tendons and palmar fascia. I believe that the depth of the infection is only a matter of degree and reflects to some extent the severity of the infection.

Despite the definition of separate palmar spaces and detailed descriptions of their boundaries and contents, Foreman (1960) noted that infections do not necessarily respect anatomical boundaries and the correct place to open all hand infections remains at the point of maximal tenderness.

THENAR AND HYPOTHENAR INFECTIONS

Infections of the thenar and hypothenar regions accounted for 33 cases in this study. They are rarely associated with complications and are treated in the recommended standard manner.

INFECTIONS OF THE WEB AND PALMAR PAD

These infections are situated in the connective tissue at the base of the fingers and in the interdigital clefts (the 1st webspace is situated between the thumb and index finger). Most of them arise from blisters at the base of the fingers and are therefore of the 'beat' type of disorder described by Collis and Llewellyn in 1924. Less frequently they are caused by puncture wounds. Palmar-pad abscesses have been recognised as a separate entity by Scott (1952), who termed them 'distal palmar pulp abscesses', though Bailey (1963) includes them under the general heading of subcutaneous infections.

Cases of infection of the web and palmar pad number 59 and 142 respectively and their combined total of 201 cases

/represents.....

represents 16% of the total of the present series.

Anatomically there is direct continuity between the web and the deep palmar spaces and theoretically infection of the former might easily spread to the latter. In practice, however, this complication seldom occurs (Pilcher et al. 1948). As the lesion progresses, pus may reach the surface through the roof of the abscess or it may track distally along the side of the proximal phalanx.

Complications do not occur in early cases, but later the underlying tendon sheath may become involved though rarely. Tissue necrosis and skin loss occur more frequently but still rarely.

Surgical drainage

Drainage is by the deroofing method (fig. 19). With web abscesses and cases in which the infection has spread along the side of the finger, I have found that drainage is effectively established by a deroofing incision at the base of the finger as

FIG. 19 Palmar pad abscess after deroofing (same patient as fig. 12 page 102)

/for.....

for palmar pad infections. Incisions at this site heal more readily than incisions of the web and side of the finger. This constitutes the only slight deviation from the rule of incising directly over the area of maximal tenderness.

MID-PALMAR INFECTIONS

The term 'mid-palmar' infection is usually applied only to infections deep to the palmar aponeurosis. I have included in this group all infections which occur in the middle of the palm and they account for 29 cases or 2.4% of the present series.

Together with lymphangitis and tenosynovitis, Flynn (1943 and 1949) considered middle palmar infections to be one of the grave infections of the hand.

Pemberton (1940) recognised the features common to palmar abscesses as constitutional symptoms, dorsal oedema of the hand and immobility of the hand and fingers the latter being kept apart. The concavity of the hand is also lost.

Plewes (1954) regarded palmar-space infections as being of major surgical importance, requiring admission to hospital and systemic antibiotic treatment in every case.

Anatomical and pathological features

Cases in which the infection is superficial to the palmar aponeurosis are easily managed and recover rapidly. Eleven in the present series were of this type. Infections deep to the palmar aponeurosis (18 cases) are another matter and are, in my experience, the most difficult of all hand infections to manage in the acute stage. Because the palmar aponeurosis is unyielding and is fixed to the bones of the hand, there is a marked increase

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in pressure with the exudation of inflammatory fluid (a situation analogous to infections of the distal volar pad). Pus ramifies between all the structures contained in the mid-palmar space and may involve the tendon sheaths.

Surgical drainage

Kanavel (1940) and other earlier authors advised drainage by way of an incision in the interdigital web and passage of a sinus forceps along the lumbrical canal. Volar incisions with dorsal counterparts and through and through drains, were also advised. Furlong (1957) used the incisions in the interdigital web and also describes Henry's approach - from the ulnar aspect of the hand, by lifting up the hypothenar muscles from the 5th metacarpal, elevating the ulnar bursa and opening the palmar space from that aspect.

Incisions in a skin crease over the maximal point of tenderness dividing the palmar fascia at right angles to its fibres and removing all slough, were advocated by Plewes (1954).

Where the infection has extended deep to the palmar aponeurosis, linear incisions drain inadequately and I have usually found it necessary to deroof a large area and excise the underlying palmar aponeurosis. The abscess can then be adequately explored and cleaned and does not close prematurely. Disability due to the incision has never resulted and one can only stress once again that inadequate drainage is likely to give poor results.

INFECTIONS FOLLOWING HUMAN BITES

Human bite infections are notorious for their severity.

/Mason.....

Mason and Koch (1930) held that 3 factors accounted for this, namely, the symbiosis of the spirrilum and fusiform organisms of Vincent, the site and depth to which the infectious agent is introduced and the anatomical arrangement of the joint capsules and of the fascial layers of the dorsum of the hand.

Cases were described and the literature reviewed by Cohn (1940) and Grimes and Manges (1949). Most of their cases were MP and PIP joint infections caused by the closed fist striking the teeth of another man. Grimes and Manges found mixed organisms in the infections, most frequently staphylococci, streptococci and bacillum proteus. They recommended admission to hospital of all cases, standard surgical drainage, rest and antibiotics and condemned the suturing of wounds.

In the present series there are 7 cases of human bite infections. These were caused by true bites rather than the striking of the fist against the teeth of another man. Because of the mode of injury, there are several portals of entry, on both the dorsal and the volar aspects; tissues may be devitalised and joints are not infrequently penetrated, thus providing an ideal set of circumstances for the establishment of a severe infection.

Bacteriological studies were made in 4 cases and the organisms found were staphylococci (3 cases) and staphylococci and streptococci (1 case).

Spreading infection (cellulitis) was present in 6 cases, one of these also suffered osteitis, septic arthritis and tenosynovitis and another one osteitis of the distal phalanx.

/Erysipeloid.....

ERYSIPELOID

Erysipeloid is a type of infection of the fingers and hand which is frequently reported in series of hand infections. The condition was reviewed by MacDougall (1951). It is a specific infection caused by Erysipelothrix rhusiopathiae and is reputed to be easily confused with cellulitis due to pyogenic organisms. I have not seen any cases in the mining industry conforming to the reported clinical features.

THE COMPLICATIONS OF HAND INFECTIONS

In this section the complications of hand infections, as distinct from the sequelae (e.g. amputated or stiff fingers), are discussed. The rationale of the present classification, including the complications, has been discussed in the chapter on 'classification'.

A simple infection is here defined as one in which only skin and subcutaneous tissue are involved. The infection is regarded as being complicated when it extends to bones, joints or tendon sheaths, or where body defences cannot contain the local infection and cellulitis, lymphangitis, thrombophlebitis or septicaemia results. Excessive skin loss has also been included as a complication.

This approach, which has not been used in previous work on hand infections, has been found invaluable for the following reasons:

1. It provides an easy and accurate classification.
2. It furnishes criteria for the administration of antibiotics.
3. Similarly it enables surgical procedures to be standardised.
4. Prognostication of time off work and the end results are facilitated.

While any hand infection might result in complications, those at certain sites are far more liable to do so.

/By.....

By these criteria 262 of the cases in this series showed complications. Of these 233 (89%) presented with the complications and the remaining 29 (11%) developed them at a later stage.

Infections of the Tendon Sheath (Tenosynovitis)

Infections of the tendon sheath are considered to be a rare occurrence. An incidence of about 3 per 1,000 hand infections was quoted by Anderson (1954).

Kelly and Jacobsen (1964) state that the most commonly encountered type in the industrial setting is stenosing tenosynovitis and only mention acute infectious tenosynovitis in passing. This may be true for their particular industry, but their views are not supported by the literature. In the gold mining setting I have not encountered a single case of stenosing tenosynovitis, though many cases of acute suppurative tenosynovitis are seen.

Tenosynovitis figures from the Industries Injuries Insurance office of Sweden for 25 years (1929 - 1953) were reviewed by Aronsson (1955). This included only cases with verified diagnosis leading to at least 10% disabality and totalled 411 cases. Aronsson found a marked decline in incidence from about 1944 and attributes it to better treatment and earlier reporting (as a result of employing industrial health medical officers) and the use of penicillin.

Tendon Sheaths - Anatomical Aspects

Synovial membrane, with its fibrous capsule, lines joints, bursae and synovial tendon sheaths. Its function is concerned with the secretion and absorption of synovial fluid,

/which.....

which lubricates and nourishes gliding surfaces and keeps them free from debris. The "synovial sheaths" of the carpal and digital tendons are merely elongated bursae (Barnett, Davies and MacConnail 1961).

The parietal layer of the sheath is firmly attached to the surrounding structures, the visceral layer firmly attached to the tendon and the visceral and parietal layers glide on each other.

Tendons in the hand receive their blood supply from the descending vessels from the muscle belly, which anastomose with ascending vessels from the periosteum at the tendon insertion and from blood vessels perforating the sheath through a synovial fold called a mesotendon or vinculum (Last 1959).

The tendon sheaths terminate immediately distal to the proximal septum of the pulp-space (Wilkinson 1950 - 51) and those of the index, middle and ring fingers commence opposite the heads of the metacarpal bones, but with a special arrangement for the thumb and little finger. The tendon sheaths extend proximally a short distance beyond the upper limit of the flexor retinaculum into the forearm.

The sheath of the flexor pollicis longus is also termed the 'radial bursa'.

The digital sheath for the little finger, known as the ulnar bursa, communicates with the common flexor sheath in front of the wrist, while in the case of the 2nd, 3rd and 4th digits the common sheath does not extent to the fingers, but ends

/in.....

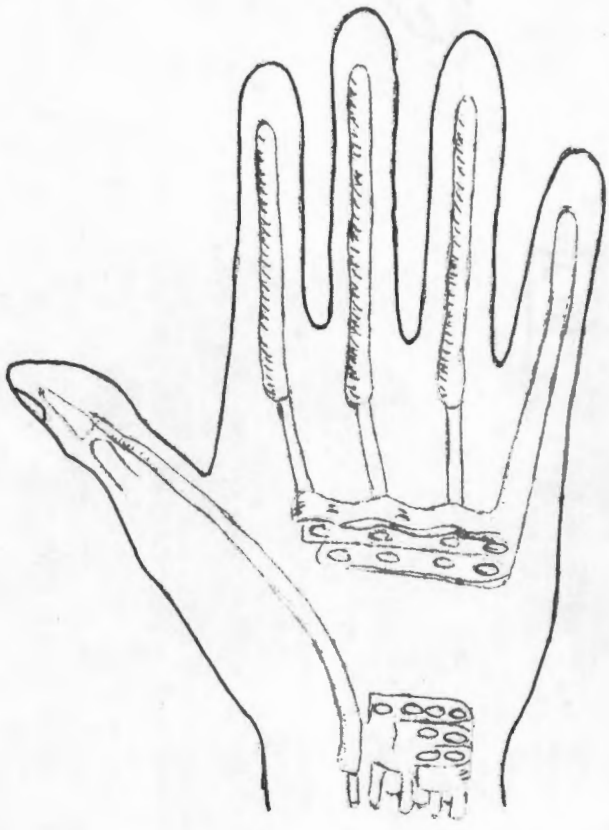


FIG. 20 Diagram illustrating synovial sheaths

in 3 blind pouches at about the middle of the metacarpal bones. The common flexor sheath communicates at the level of the wrist with the sheath of the flexor pollicis longus in 50% of individuals (Bunnell 1956, Last 1959). See fig 20.

The importance in hand infections of the close association of the volar finger creases (the middle and distal creases in particular) with the tendon sheath, has been discussed in previous chapters.

The Pathogenesis of Tenosynovitis

Grinnel (1937) in an excellent paper on tenosynovitis, reviewed the subject and studied 125 cases collected over a 17 year period. The infection was by direct inoculation in 67 cases,

/and secondary.....

and secondary extension from a neighbouring infection in 54 cases. Rarer causes included infection via the blood stream e.g. gonococcal tenosynovitis (also described by Birnbaum and Callender 1935) and lymphatic spread from a more distant source.

Although recent authors attribute nearly all cases of tenosynovitis to direct punctures (Gordon 1950, Plewes 1954, Bailey 1963) in the present series only 3 cases could be attributed to penetrating injuries and the remainder resulted from extension from a neighbouring infection.

When infection develops in the digital sheath of the index, middle or ring finger, the sheath distends and may rupture proximally into the palm of the hand (Aird 1957) - this occurred in 1 case in the present series. Infection of the sheath of the thumb or little finger may spread proximally more readily.

Diagnosis of Tenosynovitis (Literature)

The classical description of tenosynovitis is that of a symmetrically swollen finger held in a semiflexed position, with exquisite pain on extension and tenderness limited to the distribution of the sheath (Koch 1929, Kanavel 1940) and these features are still accepted by the majority of writers.

Moses (1946) maintained that the classical signs were not pathognomonic either singly or in combination and might be confused with cellulitis and lymphangitis. He devised a clinical test which he considered more reliable. The nail of the involved finger is held by the examiner so that actual flexion of the tissues is not allowed. On attempted flexion of the finger the patient with tenosynovitis is said to feel pain along the palmar

/aspect.....

aspect of the finger due to the tensing of the tendon against the sheath. Plewes (1954) also considers this a useful sign.

Iselin (1940) discusses the usual general signs of tenosynovitis - intense pain, fever, general malaise and a semi-flexed finger which is impossible to straighten (Hook's sign), with characteristic pain along the sheath. He concludes however that the only certain sign of tenosynovitis is the discovery of the denuded tendon in the depth of a wound that has been explored under general anaesthetic with a bloodless field.

New Diagnostic Procedure

On the basis of observations, I have developed a new approach to the diagnosis and management of tenosynovitis. In the first instance, I noticed that in some cases of volar finger infections the sheath was open at the time of operation, exposing a small area of tendon and discharging synovial fluid. Clearly these were cases of tenosynovitis which had not been suspected clinically. They healed rapidly with no further surgical procedures.

As a result of this observation, I deliberately looked carefully for the tendon sheath in all volar infections of the fingers. In a surprising number the sheath appeared distended and in some cases it had lost the healthy glistening white appearance, having instead an opaque, waxy-white or yellowish colour. From these tendon sheaths one could variously obtain either no synovial fluid at all, excess of clear synovial fluid, turbid synovial fluid or synovial fluid with frank pus in it.

From these observations I conclude that tenosynovitis can only be adequately diagnosed at operation, most frequently by

/the.....

the demonstration of synovial fluid which is turbid or contains frank pus, or of a sheath already destroyed by infection. (The clear synovial fluid is, I believe, analogous to the sympathetic effusion in a joint situated close to an infection. I have also found synovial sheaths distended with clear synovial fluid in cases of acute traumatic synovitis).

When the classical signs of tenosynovitis are present, the diagnosis will usually be confirmed at operation. In my experience the biggest drawback of relying on these signs is that the earliest cases are often missed. In other cases they are diagnostically incorrect and may be simulated by volar infections with cellulitis.

Treatment of Tenosynovitis

Of all the types of hand infection, acute suppurative tenosynovitis has shown the greatest improvement in results, especially with the advent of penicillin. Comparing the results of cases treated in 1943 with and without penicillin, Cruikshank and Harrison (1947) found systemic penicillin to be effective in the treatment of tenosynovitis.

Incisions of the synovial sheath along its entire length, leaving only small pulleys, with or without incisions in the palm were described by the earlier writers (Koch 1929, Kanavel 1940, Iselin 1940, Colonna 1940, Florey 1944) and are still used by some more recent writers (Bunnell 1956, Farquharson 1962, Entin 1964).

Anderson (1954) described limited lateral incisions with incisions in the palm. Other recent authors favour limited palmar

/incisions.....

incisions and distal finger incisions, and then irrigation of the sheath with a penicillin solution (Murray 1951, Bailey 1963).

Lowden (1964) advocated rest and antibiotics at first and resort to surgery if there was no response. In tenosynovitis resulting from local infection, he first drains the local abscess and follows this by proximal drainage of the tendon sheath at a separate opening of the sheath.

Others have not used surgical incisions, but have treated their patients by aspiration of the tendon sheath and instillation of penicillin (Grossmark and Plewes 1954).

Proposed Treatment of Tenosynovitis

In my opinion the radical surgical approach is unnecessary and gives rise to prolonged time off work and a high rate of residual disability. Nevertheless, surgical measures are an important diagnostic procedure. The diagnosis of tenosynovitis cannot be made reliably on clinical grounds and I do not therefore agree with the writers who simply aspirate and instil antibiotics.

My procedure is to explore the original infection or puncture wound by the standard deroofing incision. The tendon sheath is inspected and if it is distended, opaque or yellowish I make a small longtitudinal incision in it. The presence of turbid synovial fluid or pus in the sheath, confirms the diagnosis of tenosynovitis.

This local incision suffices for drainage of the sheath, and no further incisions are made, even if the radial or ulnar bursa is infected (this is diagnosed by the discharge of copious turbid synovial fluid when the palm is pressed at the appropriate site).

/I do.....

I do not give antibiotics where no fluid or only clear synovial fluid is obtained and contrary to generally accepted views, incisions in the synovial sheath carried out in this way, have not resulted in tenosynovitis. Where the diagnosis of tenosynovitis has been confirmed I give systemic antibiotics only; they have been shown to penetrate adequately into synovial cavities. (Florey, Chain et al. 1949)

Analysis of cases

On the basis of the preceding discussion, 92 cases or 7.2% of the total were diagnosed as having tenosynovitis. Of these, the tendon sheath was found to be already open at the time of operation in 49 cases, and in 43 cases turbid synovial fluid or pus was demonstrated by opening the tendon sheath. Radial and ulnar bursa infections were present in 3 and 4 cases respectively.

A further 40 tendon sheaths were incised and of these 'no fluid' was found in 25 and clear fluid in 15. In this group none of the patients initially received antibiotics, though one case in which excessive clear synovial fluid was initially noted discharged turbid synovial fluid 2 days later and was given penicillin. No disability as a result of the incision resulted in any of these cases and their return to work was not delayed.

The relationship of tenosynovitis to the original site of infection is shown in table XXIII.

/Further.....

Table XXIII

Original Infection	No. of cases	Tenosynovitis	% Tenosynovitis
Distal volar crease finger	72	23	32.0
Middle volar crease finger	70	34	48.6
Proximal volar crease finger	44	3	6.8
Distal volar pad finger	157	3	1.9
Middle volar pad finger	41	5	12.2
Proximal volar pad finger	59	15	25.4
Palmar pad and web	201	5	2.5
Mid-palmar	29	2	6.9
Hypothenar	18	1	5.6
DIP joint	46	1	2.2

Further results are given in the chapter on the "results of hand infections".

Infections of Bone (Osteitis)

Acute infections may spread to involve any of the bones of the hand, though by far the greatest number occur in the distal phalanx as a complication of infection of the distal volar pad. Some of the aspects of this complication are discussed in the chapter dealing with distal volar pad infections. Koch (1937) noted that infection occurs by continuity and that nowhere is osteomyelitis secondary to infection of the overlying parts commoner than in the distal phalanges (fig. 21).

Pathological changes

Klapp (1923) described 3 stages of bone necrosis:

1. Partial necrosis in which a small sequestrum is necrosed.
2. Total necrosis which is always accompanied by arthritis and sometimes necrosis of the head of the 2nd phalanx.
3. Subtotal necrosis which affects the shaft and tip and respects the base, the line of separation forming at the level of the metaphysis.

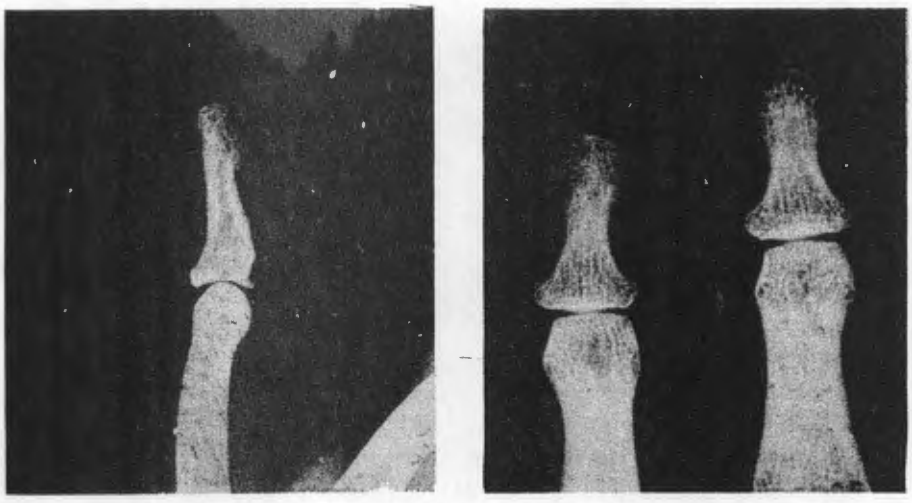


Fig. 21. Early osteitis of the distal phalanx - note relation to soft tissue lesion.

(a) (b)

Fig. 22. (a) Distal phalanx almost completely removed.
(b) Regeneration at $3\frac{1}{2}$ months.

Three types were also described by Lowden (1951)

Type I. Terminal subonychia or osteitis of the tip of the phalanx.
Type II. Superficial osteitis.
Type III. Massive necrosis with formation of sequestra.

My views on osteitis of the distal phalanx are as follows:-

Bone involvement occurs as a result of continuity from a soft tissue infection. A small area of periosteum necroses exposing the surface of the bone and cutting off its superficial blood supply. This in turn leads to erosion of the surface of the bone which separates exposing underlying cancellous bone. Progression of the osteitis may now take place in two ways, namely by spread through the bone or by further restriction of blood supply, due to either necrosis or lifting of the periosteum. (In very severe or neglected infections of the distal volar pad, I have sometimes noted an intact distal phalanx completely denuded of periosteum lying in a bed of pus).

Initially further spread is limited by the firm attachement of the articular capsule and the tendons with their rich blood supply, but if this barrier is breached the remainder of the bone, the distal interphalangeal joint, the tendon sheath and proximal soft tissues are frequently involved individually or simultaneously.

Diagnosis of Osteitis

Aird (1957) stated that bone infection should be presumed if the following signs are present: a discharging sinus or wound present for 10 days or more; club-like swelling of the distal ⅓rd of the finger; the development of a spontaneous

/sinus.....

sinus (Klapp's sign); the spread of infection round the edge of the nail or into the interphalangeal joint; or massive soft tissue slough extruded at operation. Apart from infection spreading round the nail, these signs are reasonably reliable, but may indicate only a late stage of infection.

The earliest diagnosis of osteitis can be made by the demonstration at operation of bone denuded of periosteum. (This has a characteristic rough feel when touched with the point of a probe or mosquito forceps).

It is generally believed that changes in the X-ray appear. nces are not seen in bone infections until 2 - 3 weeks have passed (Aird 1957). In acute haemotogenous osteomyelitis in children Green, Nyhan and Fousek (1956) found that the average interval from the onset of symptoms to development of the X-ray signs was 10 days with a range of 3 - 17 days. In infections of the distal phalanx I have frequently seen X-ray changes within the first week.

In late cases, with sequestra, the diagnosis of osteitis cn X-ray is obvious, but the earliest signs are not readily appreciated and are usually labelled as simple osteoporosis due to the adjacent soft tissue infection. I have found that radiological signs of a small local erosion, periosteal reaction or rarefaction indicate involvement of bone which can readily be demonstrated at operation.

Surgical Treatment

Klapp (1923) and Iselin (1940) treated their cases initially just as if there was no infection of bone. They stated that if sequestration was inevitable it was obvious at the

/end.....

end of 10 days or a fortnight and they then removed the sequestrum.

Macey (1940) recognised restoration of distal bone and therefore advised that extrusion of sequestra should be allowed to take place spontaneously. Bolton, Fowler and Jepson (1949) also did not remove sequestra. Most recent authors advocate the removal of loose fragments of bone only and await signs of demarcation before removing further bone (Marble 1960, Bailey 1963).

Amputation has been advised where osteitis is associated with septic arthritis (Iselin 1940, Macey 1940, Farquharson 1962).

It is my opinion that surgical drainage in early cases of osteitis should be limited to drainage of the soft tissue. Where sequestra are present they should be removed immediately. In the cases where the distal phalanx is denuded of periosteum I have removed this portion in spite of the fact that it may still be firmly fixed to the proximal portion and have invariably found that the marrow cavity was full of pus. A surprising degree of regeneration of the distal phalanx may take place in cases where bone is removed but periosteum remains intact (fig 22).

Where the whole distal phalanx has become sequestrated and the soft tissues are reasonably healthy, I have in some instances removed only the bone. In these cases the soft tissues have become firm and the patient has been left with a useful distal volar pad, especially when the nail is still present.

While, then, proposing a more radical approach to the removal of dead bone, I do not believe that amputation should be resorted to as readily as some writers have advocated.

/Antibiotics.....

Antibiotics

Together with surgical drainage, antibiotics form the cornerstone of the treatment of osteomyelitis elsewhere in the body (Shandling 1960, Tronzo and Dowling 1962, Meyer, Kieger and Smith 1965, Louw 1965), and there is uniform agreement that cases with osteitis of the hand should receive antibiotics.

Although very early cases of osteitis of the distal phalanx, and also very late cases with sequestra in which the acute signs of inflammation have settled may be treated without antibiotics, I am of the opinion that all cases of osteitis should preferably receive an antibiotic.

Analysis of Cases

There were 76 cases of osteitis in the present investigation. The distal phalanx was involved as a result of infection of a distal volar pad in 62 cases (40%) of such infections. This is a higher incidence than the 15 - 25% rate reported in the literature.

Osteitis of the distal phalanx also occurred in 4 cases (10%) of dorsal infection of the distal phalanx and 2 cases (4%) of paronychia.

Eight cases of osteitis occurred secondarily to septic arthritis (fig 23).

Sequestrectomy was performed in 11 cases. Of these approximately the distal three quarters of the distal phalanx was removed in 8 cases, of which 3 were not demarcated, and the whole distal phalanx in 3 cases.

/Infections.....

Infections of Joints (Septic Arthritis)

Septic arthritis can be defined as a bacterial or mycotic infection of the synovialis with or without extension to the joint space. It may be caused by implantation (penetrating injury etc.,), extension from adjacent bone or soft tissue infection, or haematogenous spread (Ward 1964).

In the present as in other series of hand infections septic arthritis usually results from a penetrating injury of the joint and less often from direct spread from an adjacent focus of infection. Septic arthritis due to haematogenous spread is very rare in hand infections and was not encountered in this investigation.

Diagnosis

The classical signs of septic arthritis are a tender, hot joint with pain on all movements, crepitus and abnormal lateral mobility. The earliest X-ray changes are a reduction in the joint space and blurring of the articular margins (fig 23).

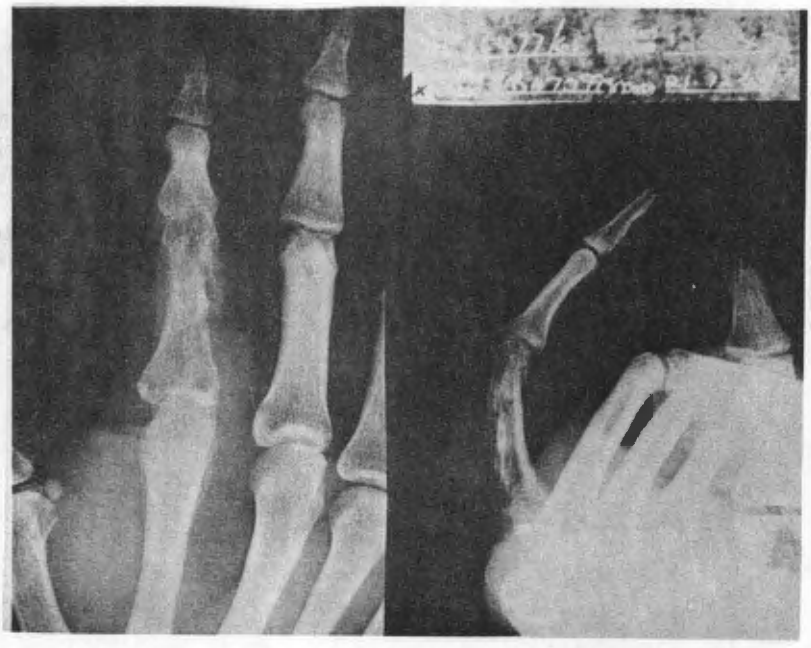


Fig. 23. Osteitis of proximal phalanx and septic arthritis of P.I.P. and M.P. joints at 3 weeks.
(Note subluxation of M.P. joint and periosteal reaction extending to metacarpal).

These changes all indicate an advanced infection and results in these cases are invariably poor. As in tenosynovitis, I believe that the earliest cases can only be accurately diagnosed by the demonstration of turbid synovial fluid or pus in the synovial fluid.

Management (literature)

Wide exposure of the joint with joint toilet and subsequent suture of the skin has been recommended. (Riddel 1950, Robins 1952).

Others have recommended aspiration of the joint and injection of a drop of penicillin under general anaesthetic (Plewes 1954).

For treatment of septic joints elsewhere in the body, Ortiz and Miller (1961) repeatedly aspirate and instil antibiotics and, if no improvement is apparent in a few days, they incise and drain the joint. Ward (1964) advocates a similar approach, but only uses systemic antibiotics.

Proposed Treatment of Septic Arthritis

The method of treatment adopted in the present series was as follows:

The local infection or site of injury is explored through the deroofing incision and if joint involvement is suspected it is aspirated through the same incision. The demonstration of turbid synovial fluid confirms the diagnosis of septic arthritis and a small incision is made in the joint capsule to allow for drainage (because of the small size of the joints of the hand, pressure builds up rapidly in the infected

/joint.....

joint and repeated aspiration is impracticable - I consider therefore that open drainage is an essential part of the treatment). In cases which do not settle down the joint is opened widely to remove pus, debris and loose articular cartilage.

There is general agreement that antibiotics should be given in septic arthritis and I generally use systemic antibiotics only which are known to penetrate adequately into joints (Florey, Chain et al. 1959, Jocson, 1955).

While the infection is active, the affected finger may be splinted in the position of function with an aluminium splint.

Ayalysis of Cases

There were 66 cases of septic arthritis in this series. The MP joint was involved in 29 cases and the PIP joint in 22 cases. The DIP joint is much less vulnerable to puncture wounds and though it was involved in 15 cases, these mostly resulted from adjacent soft tissue or bone infection.

Spreading Infection (Cellulitis)

Cellulitis has been defined as a spreading inflammation of subcutaneous tissues, usually those superficial to the deep fascia (Aird 1957).

The majority of pyogenic abscesses are well defined and localised. The term "cellulitis", as used in the present study, denotes infection in which the organism is particularly virulent, or the tissue response poor, so that the body is unable to localise the infection.

Streptococci are said to be the most frequent cause of cellulitis, but in this series staphylococci predominate.

/Clinical.....

Clinical features of cellulitis. The skin is irregular and tender and blisters and blebs may be present. On incision extensive liquefaction of the subcutaneous fat and necrosis of the subcutaneous tissues is usually found. The pus is blood-stained and watery.

Treatment. Unless the affected area is rested and the patient is given antibiotics the process tends to spread. When the infection has localised, the usual surgical drainage is used.

Analysis of cases. Cellulitis or spreading infection was encountered in 65 cases (5%) in the present series.

Lymphangitis and Enlarged Lymph Nodes

The presence of enlarged and tender regional lymph nodes is regarded by most authors as an indication for the administration of antibiotics.

Although lymphangitis has been included under the complications, I am of the opinion that is should rather be regarded as one of the features of inflammation and possibly an indication of the severity of inflammation, in a similar way to oedema of the hand and pyrexia.

In my opinion antibiotics should not be administered by routine in these cases though it might be argued that enlarged lymph nodes is evidence of spread of infection. The rapidly spreading lymphangitis of streptoccal infections is another matter and should be treated vigorously with the appropriate antibiotics.

In this series about 20% of cases had enlarged, tender regional lymph nodes, which all settled satisfactorily on treatment of the primary infection on its merits.

Extensive Skin Loss

Necrosis of skin, especially where there is an underlying tendon often requires further surgical procedures.

Robins (1952) pointed out that even when skin necrosis has apparently been considerable, the resulting skin loss of often slight and healing is rapid once the inflammatory oedema subsides. In a small proportion of cases however, there remains a granulating defect, which should be covered with skin graft as soon as the area can be made sufficiently clean.

Analysis of Cases

In the present study there were 19 cases with extensive skin loss and skin grafts were applied in 6 of these. An analysis of the six is given in table XXIV.

Table XXIV

Hand Infections - Cases Requiring Skin Grafts

Case No.	Initial Infection	Type of graft	Result (at 2 months)
151	Proximal volar LRF - tenosynovitis, skin loss	Split skin graft	Partial restriction of movement, (assessed at 3% disablement)
160	Middle volar crease LLF - tenosynovitis, skin loss	Split skin graft	Loss 10° extension PIP & DIP joints. Flexion 15% Short at PIP joint
184	Middle volar crease LRF - tenosynovitis, skin loss thrombophlebitis	Cross arm flap	20° flexion deformity PIP joint with active flexion to 85°. DIP joint movement limited to 70° from straight
793	Proximal volar pad LRF - skin loss, cellulitis	Split skin graft	Full function
844	Dorsum proximal phalanx LIF - skin loss	Split skin graft	Full function
1349	Proximal volar pad R. thumb - skin loss, cellulitis	Split skin graft	Loss of 10° extension and 30° flexion IP joint

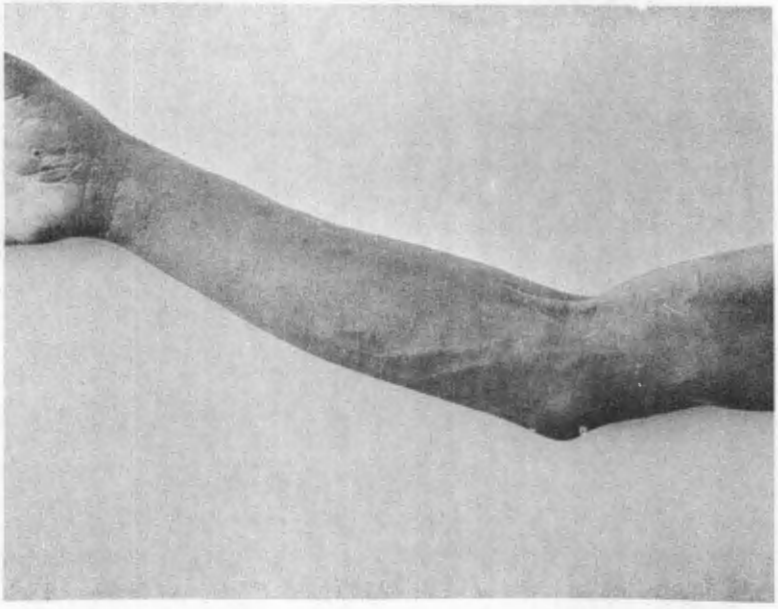


Fig. 24. Superficial venous thrombosis.

Note: Wound of old infection on hand.
Inability to straighten arm.

THROMBOPHLEBITIS

Thrombophlebitis of the superficial veins of the forearm was encountered in 3 cases. In the acute stage veins are evident as tender, palpably thickened cords, and if they extend beyond the cubital fossa, the patient is unable to straighten his arm (fig. 24). Two patients had thrombophlebitis when they first reported while the remaining patient presented with obviously thrombosed, though non-tender superficial veins of the forearm 3 weeks after discharge from hospital and was able to return to his work, without treatment apart from rest, after 2 days.

I regard the presence of thrombophlebitis as perhaps the only true contra-indication to the technique of intravenous regional analgesia which is described in the Section III.

Rare Complications of Hand Infections

Septicaemia following hand infection is a rare occurrence nowadays and no cases were encountered in the present investigation.

Median nerve palsy associated with acute infection of the hand has been described by Bailey and Carter (1955) and would appear to be an extremely rare complication of hand infections.

Amputations

Most amputations following hand infections are an end result of one or more complications. In all reported series with large numbers of cases there are a few patients who have undergone amputation or partial amputation of digits. In the

/present.....

present series they amounted to 0.4%.

There can be no hard and fast rules concerning amputation of digits. Each case must be dealt with on its own merits, with careful consideration of a number of factors, such as the site and severity of the infection and the age and occupation of the patient.

In the pre-antibiotic era, fingers and even limbs were not infrequently sacrificed in an attempt to stem the tide of spreading infection. Grinnel (1937) in his series of 125 cases of tenosynovitis, reported 8% amputations, including 3 arms.

Amputation has been advised for combinations of osteitis, septic arthritis and tenosynovitis and for sloughing tendons disorganised joint and gangrene (Wilkie 1938, Iselin 1940, Macey 1940, Farquharson 1962). Amputation should never be performed when the inflammation is at its height (Wilkie 1938).

I am of the opinion that all cases should initially be treated along the lines discussed in this thesis and that a more rational decision can be made with the co-operation and consent of the patient when the acute inflammatory processes have settled down. A surprising degree of function may return even in the most severe cases, as illustrated by the following case reports from this series.

Case No. 725. This patient had a severe infection of his right index finger with a cellulitis, osteitis of the proximal phalanx and septic arthritis in both the MP and PIP joints (fig. 23). He was treated by drainage of the joints, systemic penicillin, rest and subsequent physiotherapy. At two months he had a useful and painless finger, though with restricted movements.

Case No.1308. This patient who had osteitis, septic arthritis tenosynovitis and extensive tissue destruction of the distal phalanx of the thumb, was treated by sequestrectomy of the whole distal phalanx of the thumb and extensive removal of dead tissue, rather than immediate amputation. At 2 months, the distal phalanx was starting to regenerate and though shortened, a more useful thumb than one with no distal phalanx, was the result.

Case No. 184. This patient had extensive skin loss from the middle volar crease of the right middle finger, exposing tendon. The site was grafted with a cross arm flap. He was off work for 64 days - the longest period off work in the present series - but was finally assessed as suffering only $3\frac{1}{2}\%$ disability.

These cases illustrate the point that it is possible to retain useful digits despite severe infections. There remain, however, a small group in which amputation may be advisable because the treatment time will be reduced and the end results in terms of function are likely to be as good as, or even better than (for example) a stiff finger in a poor position or a painful joint with poor function.

Amputation was performed on 5 cases in this series (0.4%) each a partial amputation of a digit (table XXV).

/Table XXV.....

Table XXV

Analysis of Amputations

Case No.	Infection	Site of Amputation
47	Distal volar pad LMF - osteitis, septic arthritis, tenosynovitis, skin loss	Distal phalanx
756	Distal volar crease LIF - osteitis, septic arthritis, tenosynovitis, cellulitis	Mid middle phalanx
774	Dorsal PIP crease LMF - osteitis, septic arthritis	Neck of proximal phalanx
1140	Middle volar crease RLF - tenosynovitis, skin loss	PIP joint
1201	Distal volar pad RMF - osteitis, septic arthritis, tenosynovitis, cellulitis	Distal phalanx

RESULTS OF HAND INFECTIONS

One of the striking features of a survey of the literature of hand infections is the vast improvement in results since the second world war, the discovery of antibiotics and the establishment of hand clinics.

A comparison of results between the various reported series is difficult because of the different classifications and varying methods which have been used for describing the results of hand infections.

Results in Previous Post War Studies

Wilkes (1954) in a social and occupational study into the causes, cost and prevention of infections of the hand, found that the average time off work was 24 days.

/Grossmark.....

Grossmark and Plewes (1945) recorded an average period off work of 17 days.

In his study of pulp infections, Lowden (1951) was able to reduce the length of treatment for the cases without osteitis from 23 days in 1947 to 17½ days in 1949. The average period of incapacity for work was 21 days in cases with persistent cavitation and 51 days in those with osteitis.

Gordon (1950) based his 'expectant treatment' of hand infections on results of cases treated in 1947, (penicillin, and early surgery) 1948 (penicillin and surgery on localisation) and 1949 (penicillin, rest, heat and delayed minimal surgical interference). In the small number of cases (64 cases) treated over this period, the average attendance time was reduced from 50 days to 28 days. Various degrees of stiffness of the joints occurred in 24 of these cases.

Papers from the Infected Hand Clinic at University College Hospital, London (Pilcher et al. 1948, Bailey 1952 and Parsons 1962) show a reduction over the years in the time required for treatment. The length of treatment in days recorded by Parsons (1962) is as follows: acute paronychia (7), pulp abscess (10.7), apical abscess (6.3), web abscess (7), cellulitis (6.2), subcuticular abscess (5.6), intracutaneous infection (5.8), subcutaneous (8.3), carbuncle (8.5) and erysipeloid (5.0).

Results in terms of function have been poorly reported apart from a small number of cases dealing with a specific complication of hand infections or a special form of treatment

/and even.....

and even in these the resultant disability is described in very general terms.

Robins (1952) was able to trace 20 of 33 patients with 'felon' and osteitis. He records the results as an ugly scar (4 cases), marked wasting and deformity of pulp (7 cases), tenderness (6 cases), poor sensation (3 cases), more than 25% limitation of the DIP joint (5 cases) and amputation (1 case). Residual tenderness or stiffness was present in 6 out of 11 cases in which skin grafts were done.

Analysis of Results in the Present Investigation

In most cases comprised in this investigation, the infection was acquired in the work on the goldmines (see Section I). The individual, his employer and the insurance organisations are interested in two main issues namely:

1. How long will the man be off his work?
2. What will the final result be? (Will there be any residual disability?)

The first question has been studied by recording the number of days off work. All patients were able to return to their normal duties and there was therefore no additional period to be considered in which they performed 'light duties'. The mean lost shift rate has been calculated, for that gives the best idea of the effective lost time. (Men in the mining industry work a 6 day week; and Sunday is not a working day. By "shift" is meant a days work. A lost shift is a working day on which an injured man is not able to work).

The final results of hand infections were studied by

/assessing.....

assessing the patients 2 months after admission to hospital. This time was decided upon, because an initial survey indicated that some would not have settled down sufficiently to assess at 1 month, while it became progressively more difficult to trace the men after 2 months. A relatively small number of patients could not be assessed, but no bias was attached to their exclusion. No doubt the results represent an over-assessment of disablement, for improvement in function can be expected to continue over many months.

Assessment of disablement was made according to the schedules of the Rand Mutual Assurance Company, which are based on the Workman's Compensation Act assessments. (The Rand Mutual is responsible for all payments in respect of disability resulting from occupational injuries sustained on the gold mines).

In order to obtain a standard and impartial assessment of results, Mr. T. Coetzee, surgeon to the Oppenheimer Hospital and member of the Central Medical Board (for assessment of injuries) assessed the majority of the patients in this series. The remainder were assessed by myself and other medical officers with experience in assessing mine injuries.

Lost shifts and treatment time

The total number of lost shifts for the 1,278 cases in the present series was 7,455 giving a mean of 5.83 per patient. The histogram in fig. 25 illustrates the distribution of lost shifts amongst the patients affected.

Including the 731 Sundays that fell into it, the total 'treatment time' was 8,186 days, giving a mean 'treatment time' of 6.4 days per patient.

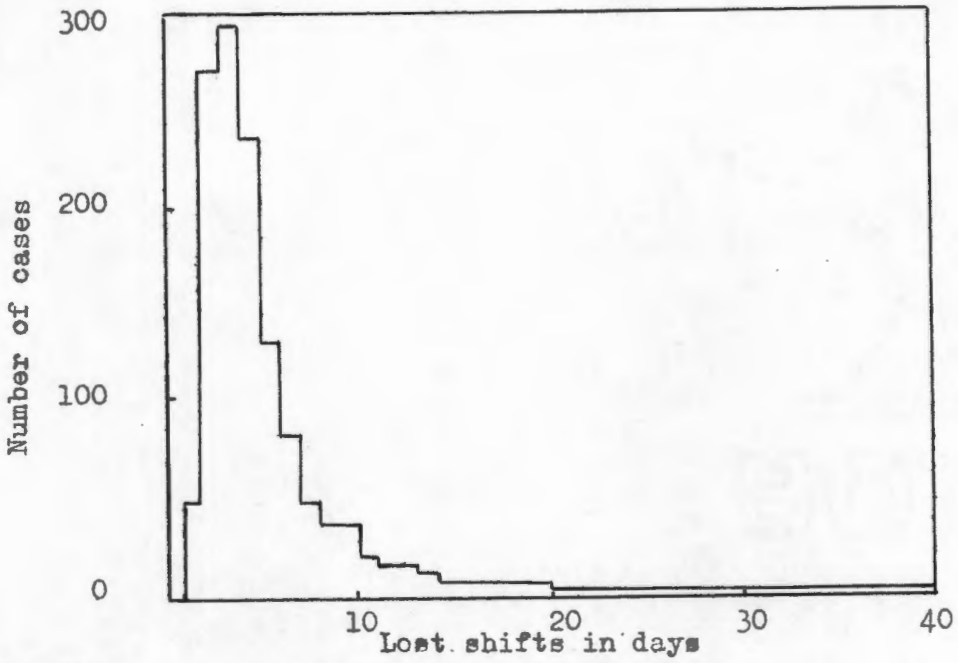


Fig. 25 Distribution of lost shifts

Table XXVI

Lost Shifts by Site of Infection

Infection	Total cases	Total shifts lost	Mean shifts lost
Distal volar pad	157	1,156	7.4
Middle and proximal volar finger pad	100	669	6.7
Volar finger creases	187	1,199	6.4
Palmar pad and web	201	1,077	5.4
Thenar and hypothenar	33	175	5.3
Mid palmar	29	183	6.3
Paronychia	44	271	6.2
Dorsal phalanges	211	1,006	4.8
Dorsal finger creases	175	1,060	6.1
Dorsum of hand	58	282	4.9
Wrist	54	253	4.7
Other	29	124	4.3
Total	1,278	7,455	5.8

Table XXVII

Disablement by Site of Infection

Infection	No. of cases assessed	No. with disablement	% with disablement
Distal volar pad	140	40	28.6
Middle and proximal volar finger pad	99	6	6.1
Volar finger crease	166	18[1]	10.8
Palmar pad and web	191	2	1.0
Thenar and hypothenar	30	-	-
Mid palmar	25	1	4.0
Paronychia	40	12[2]	30.0
Dorsal phalanges	195	8[3]	4.1
Dorsal finger creases	163	22[4]	13.5
Dorsum of hand	57	-	-
Wrist	48	1	2.1
Other	21	-	-
Total	1,181	110	9.3

1. Proximal 1, middle 6, distal 11.
2. Usually irregular nail bed or incompletely regrown nail.
3. All distal phalanges.
4. MP 4, PIP 11, DIP 7.

FACTORS INFLUENCING THE LOST SHIFT RATE AND DISABLEMENT

The most important factors influencing the lost shift rate and disablement are the site and the severity of the infection. From tables XXVI and XXVII it is apparent that the various sites at which hand infections occur differ considerably in the time

/during.....

during which they incapacitate the patient and in their proneness to leave him with some residual defect.

In my opinion there are two main features which distinguish a severe infection from a minor infection. These are the extent of soft tissue destruction caused by the infection and the presence of complications. The extent or degree of inflammatory oedema may also be a useful pointer. In preceding chapters some of these aspects have been discussed and it has been shown that delay in reporting infections increase complications and the lost-shift rate. Other factors are considered in the following tables and discussion.

Tissue Necrosis in Relation to Shifts Lost

Tissue destruction or necrosis occurs to a greater or lesser extent in all pyogenic infections. For the purpose of this study the extent of soft-tissue destruction was recorded as slight, moderate or severe. This was recorded in relation to the size of the infected part. A severe necrosis of the distal volar pad of the little finger would, for example only constitute a slight degree of necrosis if present to a similar extent on the thenar eminence.

The results of this aspect of the study are recorded in table XXVIII, which illustrates the important effect of the degree of tissue necrosis on the lost shift rate. It also shows that tissue necrosis is frequently severe, in volar finger infections, especially those of the distal volar pad.

/Complications.....

Table XXVIII

Degree of Tissue Necrosis Related to Lost Shift Rate

Site	Slight destruction			Moderate destruction			Severe destruction		
	No.	S.L.	M.	No.	S.L.	M.	No.	S.L.	M.
Distal volar pad	75	340	4.5	24	183	7.6	31	393	12.7
Middle and proximal volar finger pad	36	150	4.2	16	83	5.2	13	224	17.2
Volar finger creases	96	421	4.4	20	175	8.8	19	204	10.7
Palmar pad and web	108	487	4.5	19	113	5.9	3	40	13.3
Thenar and hypothenar	18	86	4.8	6	47	7.8	3	20	6.7
Mid-palmar	16	81	5.1	9	78	8.7	-	-	-
Paronychia	27	119	4.4	3	36	12.0	-	-	-
Dorsal phalanges	137	566	4.1	26	135	5.2	5	79	15.8
Dorsal finger creases	117	658	5.6	11	68	6.2	5	81	16.2
Dorsum of hand	41	179	4.4	2	25	12.5	-	-	-
Wrist	31	118	3.8	6	56	9.3	-	-	-
Other	11	43	3.9	2	11	5.5	-	-	-
Total	713	3,248	4.6	144	1,010	7.0	79	1,041	13.2

No.= Number of cases S.L.= Total shifts lost M.= Mean shifts lost

Complications in Relation to Shifts Lost

Complications according to the classification proposed in the chapter under that name occurred in 277 cases in this investigation (21.7%). These cases accounted for 2,811 lost

/shifts.....

Table XXIX

Complications of Hand Infections
Related to Lost shift Rate

Complication	No. of cases	Total lost shifts	Mean lost shifts
Tenosynovitis	92	922	10.0
Osteitis	76	957	12.6
Septic arthritis	66	787	11.9
Cellulitis	65	673	10.3
Skin loss	19	431	22.7
Total *	277	2,811	10.1

* The apparent discrepancy is due to the presence of a number of complications in some cases although each complication has been analysed individually. More than one complication in the same case indicates a more severe infection, which is also reflected in the increased lost shift rate.

shifts with a mean of 10.1 (roughly twice the rate for the whole series of cases). The results are recorded in table XXIX

The particularly large number of shifts lost in the 'skin loss' group, is the result of the further surgical procedures that are often required for patients in this group.

Oedema in Relation to Shifts Lost

Oedema was recorded in 3 grades:

1. Nil or slight - restricted to the site of infection.
2. Localised - involving a finger or part of the hand.
3. Generalised - involving the whole hand.

The cases of oedema according to site and severity are classified in table XXX in relation to lost shifts.

/Oedema.....

Table XXX

Oedema in Hand Infections Related to Lost Shifts

Site	Oedema nil or slight			Localised oedema			Generalised oedema		
	No.	S.L.	M.	No.	S.L.	M.	No.	S.L.	M.
Distal volar pad	81	409	5.0	32	284	8.9	4	81	20.3
Middle and proximal volar finger pad	21	76	3.6	29	174	6.0	11	101	9.2
Volar finger creases	47	239	5.1	58	363	6.3	26	238	9.2
Palmar pad and web	26	96	3.7	16	70	4.4	92	497	5.4
Thenar and hypothenar	4	17	4.3	9	46	5.1	14	81	5.8
Mid-palmar	4	15	3.8	1	6	6.0	20	142	7.1
Paronychia	23	95	4.1	4	40	10.0	1	4	4.0
Dorsal phalanges	47	188	4.0	87	412	4.7	33	177	5.4
Dorsal finger creases	29	127	4.4	62	413	6.7	39	256	6.6
Dorsum of hand	5	23	4.6	9	37	4.1	30	157	5.2
Wrist	6	19	3.2	11	76	6.9	22	102	4.6
Others	5	15	3.0	3	13	4.3	5	26	5.2
Total	298	1,319	4.4	321	1,934	6.0	297	1,862	6.3

No.= Number of cases S.L.= Total shifts lost M.= Mean shifts lost

Oedema is a common feature of hand infections and in general is more evident in severe infections. It occurs most frequently to a marked degree in infections of the palm of the dorsum of the hand, and of the wrist, though in the latter two sites it is not an indication of the severity of the infection. Generalised oedema is rare in distal finger infections, but when present it indicates a severe infection (especially infections of the distal volar pad.)

Age in Relation to Shifts Lost

The influence of age on the lost shift rate is demonstrated in table XXXI. Clearly age is an important factor influencing shifts lost due to hand infections. Despite the fact that extremes

Table XXXI

Lost-Shift Rate in the Various Age Groups

Age (yrs.)	No. of patients	Total lost shifts	Mean lost shifts
17 or under	11	52	4.73
18 - 20	183	972	5.31
21 - 25	522	2,824	5.41
26 - 30	288	1,750	6.08
31 - 35	120	791	6.59
36 - 40	65	467	7.18
41 or over	32	216	6.75

of age were not present in this study it is apparent from the table that even in the limited age range present there is an increasing lost shift rate with increasing age. The influence of age on staphylococcal infections is dealt with in Section I.

Tribal influences on Shifts Lost

It has been shown in section I that 'tropical' Africans are more susceptible to disease, including hand infections. Table XXXII shows the influence of tribal origin on the severity of hand

Table XXXII

Lost Shift Rate in
'Tropicals' and 'Non-Tropicals'

	No. of cases	Total lost shifts	Mean lost shifts
Non-tropical	587	3,342	5.69
Tropical	691	4,103	5.94

/infections.....

infections as measured by the lost shift rate. Though this difference is statistically significant ($p =< 0.01$) it is so small as to be of little practical importance.

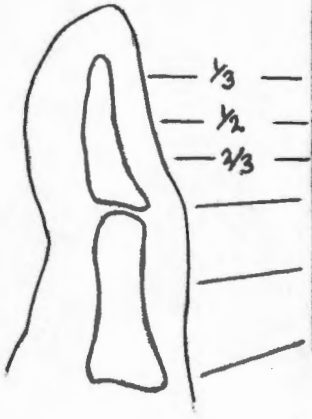
DISABLEMENT

Disablement was assessed according to the First Schedule and Supplementary Schedules 7 and 9 of the Rand Mutual Assurance Co. Ltd. (Workmans Compensation Act 1941). An indication of some of the standard assessments is given in table XXXIII:

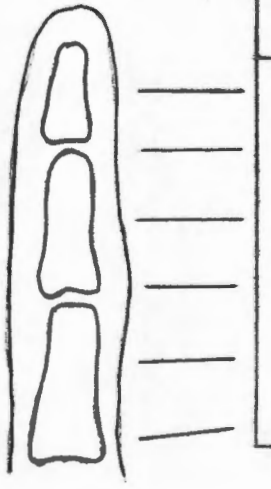
Table XXXIII

Standard Assessments for Amputations of Digits

THUMB



Inter-phalangeal joint mobile %	Inter-phalangeal joint stiff %
6	7½
10	12½
12½	15
15	-
20	-
25	-



Index %	Middle %	Ring %	Little %
3	2	1½	1
5	4	3	2
7	5	4	2½
8	6	5	3
10	8	6	4
10	8	6	4

/The schedules.....

The schedules also provide for the assessment of loss of function through stiffness of joints.

Scarring usually carries an assessment of ½ - 1% disability if the scar is adherent, disfiguring or tender. Loss of nails carries the following disability: Little, ring and middle finger ½% each; index finger 1%; thumb 2%.

Type of Disablement. The end results of infections which were assessed as having caused disablement are analysed in table XXXIV.

Table XXXIV

Type of Disablement

Disablement	No. of cases
Amputation	5
Loss of function	44
Scarring	32
Loss of function and scarring	29
Total	110

Percentage Disablement. The histogram in fig. 26 illustrates the distribution of percentage degrees of disablement amongst cases.

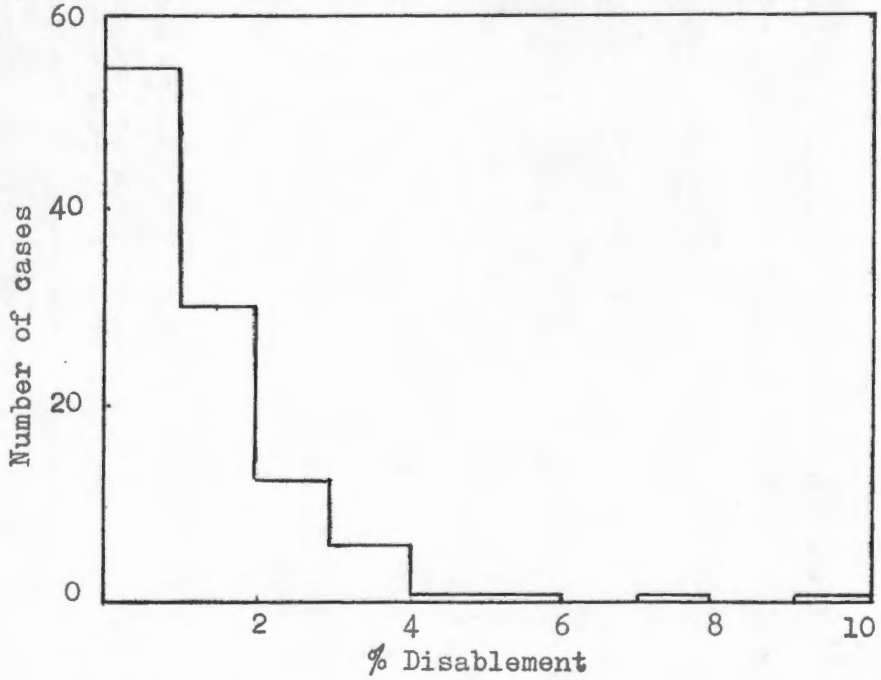


Fig. 26 Percentage disablement by number of cases

Causes of Disablement. An analysis of the causes of disablement are given in table XXXV.

Table XXXV

Causes of Disablement

Cause	No. of cases
Initial severity of infection or presence of complications	99
Delayed or late surgery	4
Subsequent flare-up of infection	3
Insufficient drainage	3
Initial severity & insensitive organism	1
Total	110

Of the 262 patients with complications, 248 were assessed, and 85 of these has residual disablement at 2 months, thus 163 patients (66%) with complications recovered with no disablement.

Discussion

It should be stressed again that all the patients in this study were able to return to their normal work with useful hands, and that in the great majority of cases the terms disability and disablement are used to denote a very moderate departure, from complete normality of the hand. Moreover, as already stated, the figures presented no doubt represent an over-assessment of disability, for function is well known to improve over a perior of many months. Amputations were assessed on discharge from hospital because standard assessments applied to them.

/The.....

The preceding figures, show that approximately 1 out of every 11 patients had some degree of disablement. In more than half of these (56 cases) it was of a very minor nature ($\frac{1}{2}$ - 1%). Moderate disablement (4% or less) was present in 50 and severe disablement (more than 4%) in 4 cases (table XXXVI).

Table XXXVI Severe Disablement

Case No.	Assessed disablement %	Description
1308	10%	Shortened distal phalanx of right thumb with loss of 20° extension and 50° of flexion (equivalent to loss of $\frac{1}{2}$ distal phalanx of thumb)
756	7.5%	Amputation through mid middle phalanx of left index finger.
774	6%	Amputation through neck of proximal phalanx of left middle finger.
47	5%	Amputation of distal phalanx of left middle finger. PIP joint flexion short by 30°.

RESULTS:

Summary and Conclusions

For the whole series of cases the lost shift rate was 5.8 days and the 'treatment time' 6.4 days. Disablement at 2 months was present in 9.3% and was of a minor degree in the majority of cases.

These results represent an improvement on results previously reported, despite the severity of the hand infections encountered in the gold mining industry.

The method of management employed (as described) provides effective treatment both for minor degrees of infection and in more severe cases, in which further damage from the infection is prevented.

SECTION III

ANAESTHESIA IN HAND INFECTIONS WITH PARTICULAR REFERENCE TO INTRAVASCULAR REGIONAL ANALGESIA

In order to allow the surgeon dealing with hand infections time for an unhurried operation and a clear view of the operating field, an effective anaesthetic and a bloodless field are most important. A general anaesthetic makes these conditions possible but my experience is that regional analgesia is the method of choice. In places where hand infections are treated on outpatient lines a general anaesthetic has the further disadvantages that the patient has usually eaten, will require premedication and will not be fit to return home unassisted for some hours.

Local Anaesthetics in Hand Infections

With newer local anaesthetic techniques all hand infections may be managed under local anaesthesia and the majority of hand infections treated in hand clinics are operated upon under regional block anaesthesia. No sepsis or serious complications have occurred in many thousands of cases of hand infections treated in this way (Bailey 1963).

Some authors add hyaluronidase to the local anaesthetic injections for nerve block in hand infections, maintaining that this has several advantages - there is little discomfort and no increased tension, the anaesthetic is quicker and healing is in no way delayed (Catchpool and Lunn 1956). Most writers, however, do not find the hyaluronidase to be of much help.

Digital Block Anaesthesia

Digital block anaesthesia may be used for operations on distal lesions of the digits, but should not be used when there is any evidence of spread of the infection.

The complications of digital block anaesthesia have been studied by Bradfield (1963). Gangrene of the finger was the only complication of consequence and factors to be considered were the degree of injury to the finger, the use of adrenaline, tourniquet time, volume of anaesthetic used and the use of hot soaks. The precautions that are suggested in the use of digital block anaesthesia are that it should not be used if there is a history of Raynaud's phenomenon, and that neither adrenaline nor hot soaks should be used.

I use the technique described by Bradfield, with the minor, but useful, technical modification of a dental syringe and cartridge, which provide a fine needle and a small volume of anaesthetic which can be accurately placed and need not be exceeded except when required in operations on the thumb. The hands are cleaned and the base of the finger is prepared for injection. The anaesthetic solution (2 ml. or less of 2% lignocaine) is injected into the side of the base of the finger - this is better than the dorsum because it is less sensitive and only one injection is necessary. The volar digital nerves are anaesthetised by placing the anaesthetic first on one side of the proximal volar pad and then on the other by passing the point of the needle across superficial to the flexor tendons, (the two dorsal nerves are not of much importance). After the needle has been withdrawn the tourniquet is applied quite firmly round the

/base.....

base of the finger, just proximal to the injection site. A convenient tourniquet is a fine rubber tube held in place with an old pair of artery forceps.

The axillary brachial block (Jolly 1962) though a most useful technique for the management of severe trauma, is too time consuming to use in hand infections; and the wrist block (Bunnell 1956, Bailey 1963) cannot be used in cases with infection of the wrist and is difficult in the presence of excessive oedema. I have rarely used these techniques in the management of hand infections.

INTRAVASCULAR REGIONAL ANALGESIA

"The most natural and simple way to bring the anaesthetic into contact with the substance of the nerve, its ramifications and the nerve ends, is by channel of blood circulation".
(August Bier - the originator of local 'vein anaesthesia' 1910)

Clinical studies of 'intravascular regional analgesia', which were begun in February 1964 and completed in May 1965, have been published (van Niekerk and Coetzee 1965, van Niekerk and Tonkin 1966). They form the basis of Section III. The large series of cases they comprise besides introducing new ideas, also affords a useful comparison between the technique of intravenous and intra-arterial regional analgesia.

Historical Background

Cocaine was isolated by Niemann in 1859 and its first use as a local anaesthetic was demonstrated by Koller in 1884, in eye surgery. Alms in 1886, injected local anaesthetic into the iliac artery of the frog, and he was the first to report its anaesthetic effect on the field supplied by the vessel used for

/injection.....

injection (Allan 1914, Adams 1944).

This knowledge was not utilised until Bier (1908 and 1910) demonstrated that effective regional anaesthesia could be obtained by injecting local anaesthetic into an isolated vascular system in a limb. Bier gives credit to workers preceding him - Reclus for the development of local anaesthesia and the use of lower doses, Schleich for developing infiltration anaesthesia and Braun, who among many other innovations introduced the addition of suprarenal extract to local anaesthetics, thus prolonging their effect, and the use of isotonic solutions to avoid irritation of the tissue.

Procaine, used by Bier and most of the other earlier workers, was introduced by Einhorn in 1905, while lignocaine was synthesised by Lofgren in 1943.

Intravenous Regional Analgesia

The technique used by Bier (1908, 1910) was to cannulise an exposed vein and inject a local anaesthetic solution into a vascular system between 2 rubber tourniquets. At the completion of the operation he 'washed out' the local anaesthetic from the vascular system with saline.

Following Bier's description several papers, were published describing experiences with his technique, including those of Morrison (1931), who modified the technique by injecting the anaesthetic solution into a vein distal to a single tourniquet and Adams (1944) who extensively reviewed the subject.

Holmes (1963) is credited with having re-introduced this technique and his method, with various modifications, has been the subject of several recent papers (Bell et al. 1964,

/Kennedy.....

Kennedy et al. 1965, Sorbie and Chacha 1965, Monty and Deller 1965, Merrifield and Carter 1965, Solomon and Berkowitz 1965).

Regional Analgesia by Injection of Local Anaesthetic Into an Artery

Bier (1910) recognised the possibility of diffusing local anaesthetic solution within the limbs by injecting it into an artery, but believed that this method would be "practically useless" because of the technical difficulties of the injection and because "it requires an important and troublesome operation to be carried out prior to the real operation".

Goyanes (1912) is cited as having described a method of arterial anaesthesia similar to Bier's venous anaesthesia in that large quantities of solution were introduced into vessels distal to a tourniquet (Ransohoff 1910, Kimmey and Steinhans 1959). A similar method was described by Braun (1913).

Ransohoff (1910) described 2 successful cases of regional anaesthesia produced by injecting cocaine into an artery distal to a cuff and discussed several animal experiments. He believed that "the nature of the anaesthesia is terminal, that is, the cocaine is carried by the capillaries to individual nerve endings".

Intra-arterial anaesthesia was discussed by Allen (1914) stating that the method was first used by Oppel and Goyanes and that "their results were quite interesting but of not much value clinically". Allen describes a partially successful case in which the external carotid artery was utilised. He stated that the addition of adrenaline to the anaesthetic was useful, and that the blanching of the area supplied by the artery afforded a useful indication when the injected anaesthetic solution had

/reached.....

reached the capillaries.

Gevorkian (1962) described local anaesthesia of the extremities produced by an arterial injection of novovaine 10% and ditilin (a curare-like preparation). He does not use stasis, however (Eriksson 1965).

Intra-arterial Injections for Other Purposes. Intra-arterial injections are commonly used in radiographic studies and local arterial perfusion for malignancy is well known. The accidental intra-arterial injections of drugs has been reviewed by Stone and Donelly (1961). Therapeutic intra-arterial injections of antiseptics and other solutions have been reported (dos Santos 1939). In peripheral arterial disease, local anaesthetics and vasodilators have been injected into the artery for the relief of pain and spasm (Leriche 1935, Auger 1962, Hankiss 1962).

Statement Concerning the Clinical Studies on 'Intravenous and Intra-arterial Regional Analgesia'

In the majority of the cases of intravenous regional analgesia the injections were administered by the author and though figures from other members of the staff of the Ernest Oppenheimer Hospital using the technique are incorporated, this was after the basic 'rules' for the use of the technique in hand infections had been defined (Van Niekerk 1964).

The technique for the administration of intra-arterial local anaesthetics was conceived and evolved by the author. Mr. Coetzee performed the first 10 arterial punctures and the author performed the remainder with slight modifications of technique. The intra-arterial analgesia cases include a small number of traumatic cases besides those with infections of the hand.

Clinical Experience with Intravenous Regional Analgesia in Hand Infections

In other published papers, intravenous regional analgesia was used mainly for trauma and infrequently for infections. It appeared to be a reliable and quick method offering good operating conditions for the surgery of hand infections and the present study was undertaken to assess its value.

Between February 1964 and May 1965, 1,000 cases of hand infections were operated on under intravenous regional analgesia, and the results were analysed. These were all inpatients and all were operated upon in the septic theatre where monitoring and resuscitation equipment was available.

Method

Most patients received 100 mg. of pethidine intramuscularly 1 hour before operation for sedation and to reduce post-operative pain.

In the theatre, a sphygmomanometer cuff was applied to the affected arm and a Gordh needle or a 22-gauge (Luer) needle with attached plastic stop was introduced into a distal forearm vein. The recumbent patient elevated his arm for a short period to empty the veins. The cuff was then rapidly inflated to a pressure greater than his systolic blood pressure to isolate the arm from the circulation. The arm was lowered and dilute local anaesthetic solution was injected through the pre-placed needle until analgesia was produced. Once analgesia was established, the necessary surgery was performed, dressings were applied and the cuff was released.

/The.....

The following points are of note:

1. No fixed maximum dose was used and because the accepted maximum safe does was not infrequently exceeded, the possibility of encountering side effects was recognised.

2. The usual 5 - 10 minute delay after injection, before surgery was commenced was not practised and patients were operated on within 5 minutes of commencing the injection. This speeded the technique considerably, but did not allow the maximal effect of the local anaesthetic to take place and higher doses were therefore required to ensure effectively.

3. Exsanguination with an Esmarch bandage is usually advocated to reduce the arm blood volume and so decrease the volume of solution required to produce analgesia. In the present series this was contra-indicated by the presence of infection.

To minimise the discomfort from the tourniquet in long operations Bier (1910) and later Holmes (1963) described a 2 cuff technique. Hoyle (1964) has described a convenient double cuff - surgical procedures in hand infections are short; few operations last longer than 10 minutes and a single cuff is well tolerated.

Bell and his co-workers (1963) recommended a 20 minute tourniquet time prior to the injection of the anaesthetic solution, thereby considerably reducing the amount of anaesthetic required, but it is felt that one of the main features of the technique, namely its quickness, is then lost.

After a number of cases had been done, it was recognised that in order to allow for free distribution of the anaesthetic solution in the arm the cuff should be applied well above the cubital fossa and the solution injected as far distally as possible (van Niekerk 1964). This point was also recognised by Sorbie and Chacha (1965).

/Skin.....

Skin Blotches and Weals

Apart from the blotchy appearance which the skin takes on after injection of the local anaesthetic, as described by Holmes (1963), I have also noted skin weals, maximal in the cubital fossa, in a number of patients, especially when a large volume is injected. The patients had no untoward reaction on release of the tourniquet, and therefore this does not appear to be significant.

Contra Indications

It has been suggested that the technique should not be used in patients with advanced arterial disease or for patients with diabetic and senile gangrene (Bier 1910, Morrison 1931).

Monty and Deller (1965) do not recommend the use of the technique in patients with cold bluish 'veinless' extremities or in extremely apprehensive patients.

Solomon and Berkowitz (1965) do not recognise any limitation provided sufficient care is taken to explain the procedure i.e. so that the patient can understand what is going to happen to him. The language difficulties in the African miners and in the series reported by Dawkins et al. (1964), proved no bar to the use of the technique.

The contra-indications to the use of intravenous regional analgesia in hand infections in my experience are:

1. Pre-existing venous thrombosis of the arm.
2. Bilateral hand infections (where the dose required to do both sides would exceed the safe maximal dose).
3. Extensive oedema making it impossible to find a vein.

/Anaesthetic.....

Anaesthetic Solution

Lignocaine, which is a widely used local anaesthetic with well recognised properties (Goldberg 1947) was used in the majority of the cases in this study.

In view of the reported longer action of mepivacaine without the addition of adrenaline (see mepivacaine package insert) this was tried in a few cases.

Reports of the low toxicity of prilocaine (Englesson et al. 1962) and chloroprocaine (Foldes et al. 1960) were noted but these preparations were not available for use in the present study.

Results

The results of the 1,000 cases are divided into 5 unequal groups according to the type and dilution of the local anaesthetic used (table XXXVII). All the patients had painful

Table XXXVII

Comparison of Groups

Group	No. of cases	Successful		Failed		Toxicity	
		No.	%	No.	%	No.	%
I Lignocaine 1% in water or saline	132	128	97	4	3	6	4.5
II Lignocaine 0.5% in water	4	1	25	3	75	1	25
III Lignocaine 0.5% in normal saline	803	801	99.8	2	0.2	1	0.1
IV Mepivacaine 0.5%	12	12	100	-	-	-	-
V Lignocaine 1% 1.5 mg/lb then saline	49	48	98	1	2	-	-
Total	1,000	990	(99)	10	(1)	8	(0.8)

lesions and injections of the local anaesthetic solution were

/continued.....

continued in 10 ml. increments until the patient was pain free. Results were recorded as 'successful' or 'failed' according as whether or not discomfort was experienced during the subsequent surgical procedure.

Group I. Lignocaine 1% was used in the first 132 cases because of the alleged inefficacy of local anaesthetics in the presence of infection (Wood, Smith and Stewart 1962). It was realised later that this was not necessary. In this group analgesia was successful in 128 cases and failed in 4. Doses of 300 - 700 mg. were administered. Six cases developed signs of cortical stimulation. Four of these became euphoric and excited and began twitching (this state was called a pre-seizure) and were controlled with small intravenous doses of thiopentone and methohexitone. The other two cases progressed to grand mal seizures. No prolonged effects were noted. The use of 1% lignocaine was abandoned because of the high incidence of side effects (4.5%).

Group II. In the second group (4 cases only) lignocaine diluted to 0.5% with distilled water was used. The 4 patients all complained of pain during the injection. Analgesia was successfully produced in 1 case and failed in 3. One case had a seizure. These poor results were probably caused by inadequate diffusion of the hypotonic solution into the extracellular fluid. Most of the injected lignocaine must have remained in the veins and been flushed into the systemic circulation when the cuff was released.

The following simple experiment demonstrated that

/hypotonic.....

hypotonic solutions cause in vitro haemolysis of fresh blood; one ml. of fresh blood was added to each of 4 test tubes containing various anaesthetic solutions and the tubes inspected after ½ hour. (table XXXVIII)

Table XXXVIII

Results of Blood Added to Various Anaesthetic Solutions

Anaesthetic solution	Result
Lignocaine 0.5% (diluted with saline)	No effect
Lignocaine 0.5% (diluted with water)	Haemolysed
Lignocaine 1% (diluted with water)	Haemolysed
Lignocaine 1% (standard solution)	No effect

It was established from the manufacturers that available local anaesthetic solutions (1% or 2%) are isotonic. Common sense would seem to indicate that when dilution is necessary, it should be done with an isotonic solution and this is supported convincingly by the findings in this group.

Group III. In this the main group of 803 cases, 0.5%

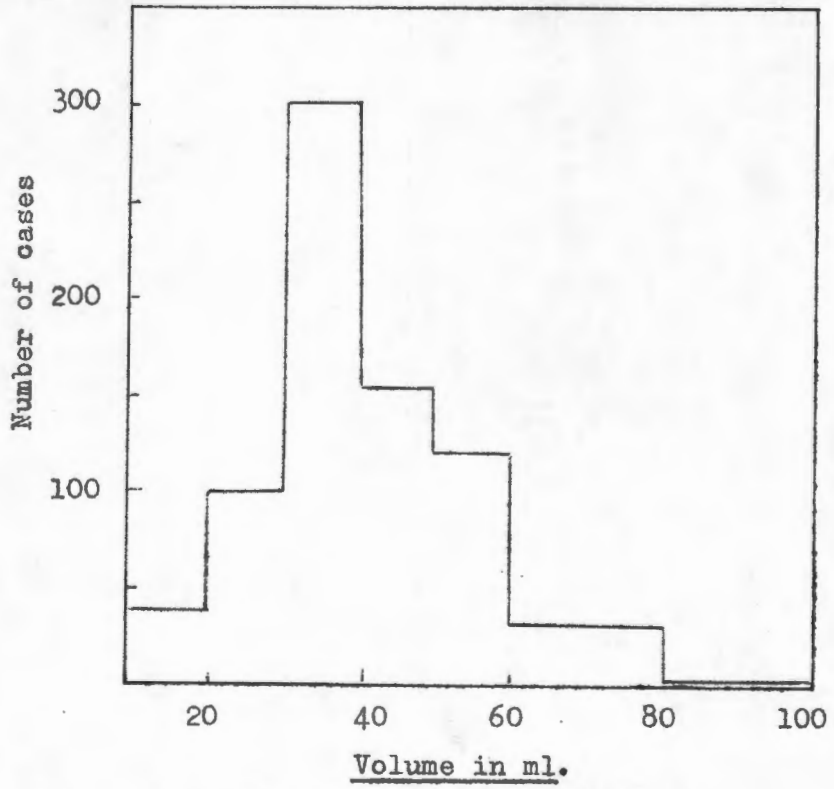


Fig. 27. Volume Distribution, Lignocaine 0.5%

lignocaine in isotonic saline was used. The best results were obtained with this solution. Analgesia was successful in 801 cases and failed in 2. One hypertensive patient had a seizure, which was controlled with methohexitone. The mean volume of 0.5% lignocaine injected was 42 ml. (210 mg) with a range of 17½ - 100 ml. The volume distribution is illustrated in fig 27.

Group IV. The sequence of cases in group III was broken by the trial of isotonic 0.5% mepivacaine in the 12 cases in group IV. Successful analgesia resulted in all 12 cases and no toxic effects were noted but 0.5% mepivacaine appeared to offer no advantage over 0.5% lignocaine. The mean volume required was 50 ml (250 mg) and the action was not prolonged after letting down the cuff.

Group V. In 49 cases 1.5 mg of 1% lignocaine per lb. body weight (just less than the mean dose used in group III) was injected, followed by a varying volume of normal saline. It was hoped that the saline would force the lignocaine peripherally to its site of action and so produce adequate analgesia. The technique was successful in 48 cases and failed in 1.

Associated Disease. The intravenous technique was also used successfully and without complications in 3 patients with myelogenous leukaemia (1) infectious hepatis (1) and mumps (1).

Return of Sensation. Return of sensation is rapid and all cases had recovered sensation within 5 minutes.

CLINICAL EXPERIENCE WITH INTRA-ARTERIAL REGIONAL ANALGESIA

Intra-arterial regional analgesia was used in 306 operations, chiefly for hand infections. The indications are shown in table XXXIX.

Table XXXIX

INDICATIONS FOR SURGERY

Indication	No. of cases
Infection	280
Laceration	6
Injury to tendons	6
Amputation	7
Manipulation	4
Multiple injuries	2
Removal of ganglion	1

METHODS

A pneumatic cuff is placed on the patient's arm, well above the elbow. The patient lies on the operating table with his arm abducted to 90° at the shoulder, extended at the elbow with the forearm supinated. In addition the arm may be elevated slightly in order to allow some emptying of the veins. A 22 gauge (Luer), short-bevel needle with attached syringe containing the local anaesthetic solution is introduced into the brachial artery near the elbow, and the sphygmomanometer cuff is rapidly inflated beyond the systolic blood pressure. The local anaesthetic solution is now injected intra-arterially, 5 ml. at a time, until the desired anaesthetic effect is obtained.

Site of Injection. Any site distal to the cuff may be used. I have injected at all sites from the lower third of the

/arm.....

arm to the radial artery at the wrist (the radial artery was used on three occasions, but the results are not included since the cuff was placed on the forearm). It is generally most convenient to puncture the artery where it is most readily palpable immediately proximal or distal to the bicipital aponeurosis at the elbow joint. Where a superficial aberrant artery is present, the task of arterial puncture is considerably simplified; in venepuncture, on the other hand, the presence of a superficial aberrant artery may lead to accidental arterial puncture.

Technique of arterial puncture. Although it is possible to enter the arterial lumen directly, it is usually simpler first to transfix the artery in a rapid movement and then withdraw the needle slowly and carefully. One may feel the "flick" as the needle frees itself in the lumen or blood may enter the needle. With narrow-gauge needles, however, blood seldom enters the syringe, and a useful guide is to allow a small air bubble to persist in the proximal portion of the needle; this, on becoming dislodged, indicates a successful puncture.

Direction of injection. The needle was directed both proximally and distally, and were both found to be effective. Although proximal direction has the merit of allowing one freedom from the cuff, in general, I preferred distal direction.

Choice of Needle. Since the anaesthetic solution is of low viscosity, a narrow-gauge needle may be used. Needles of 20, 22, and 24 gauge (Luer) have been used. With the larger needles, the possibility of damage to the artery is greater, but with smaller needles one cannot be certain whether the artery has been

/entered.....

entered. Although Gordh needles were occasionally used, I prefer an ordinary needle already mounted on a syringe containing the required anaesthetic solution. At the completion of the injection, the needle may be kept in situ and plugged with a plastic stopper.

Exsanguination of the arm. A number of the earlier failures resulted from displacement of the needle from the artery on elevating the arm in order to produce exsanguination. But since less exsanguination is required than that for intravenous analgesia, the arm may be simply inclined from the start to allow moderate venous drainage, keeping the arm in this position throughout the injection. Once analgesia has been established, the arm may be removed to any desired position.

Premedication and the double-cuff technique. Most patients were given pethidine 100 mg. as pre-medication in order to reduce discomfort from the injection, the inflated cuff, and post-operative pain related to the operation itself. Some patients (particularly those with trauma) did not receive any pre-medication. In these, and in cases where a prolonged operating time was anticipated, the double-tourniquet technique was used. This method entails the application of a second cuff distal to the first one, after analgesia has been established. Long operations may be completed with no discomfort to the patient.

Choice of anaesthetic solution. In most cases isotonic 0.5% lignocaine solution without adrenaline was used and I feel that it is superior to a similar strength of mepivacaine. In comparable groups (all hand infections and all those cases

/receiving.....

receiving pre-medication) the mean volumes required were: lignocaine 13.6 ml. (219 cases) and mepivacaine 18.7 ml. (39 cases). In a total of 237 cases the mean dose of lignocaine 0.5% was 14.0 ml. (range 5 - 50 ml.).

The original solution (1% or 2%) of anaesthetic must be diluted with normal saline so that it remains isotonic.

RESULTS

Onset of Analgesia, Signs and Symptoms

The patient feels the injection as a warm tingling sensation moving down the arm, most noticeable in the hand and especially on moving the fingers. This is followed by a sensory loss in every way similar to that of intravenous reginnal analgesia, although the onset is much more rapid. About 20% of patients find the sensation distinctly uncomfortable though brief.

Patchy mottling was more distinct than with the intravenous technique; and in infections this was more notable in the regions close to the infection.

The resultant degree of anaesthesia for all patients is shown in table XL. The amount of anaesthetic solution required varied considerably from patient to patient, and with the weight of the patient.

Table XL

Degree of Analgesia

Degree	No. of cases
Nil (failures)	22
Slight pain	9
Completely pain-free	259
Loss of all sensory perception	13
Loss of sensation and motor paralysis	3

/This.....

This variation is not surprising if one accepts that dose is related to arterial volume, and when one considers the wide variation in arterial flow in the hands of normal people (Duff 1956). A study of the relation of the dose of anaesthetic to the volume of arm (measured by displacement of water) was of no value, since the vascular changes and oedema caused by trauma and infection distorted the true anatomical picture.

Comparison of dose related to left and right arms gave mean readings of 12.8 ml. and 15.1 ml. respectively (all except 2 patients were right-handed).

Duration of Analgesia

As long as the cuff remains adequately inflated, analgesia will persist, and it even increases with time. A patient who had only loss of pain at the start of the operation, may at the end of a 45 minute operation, have complete sensory and motor anaesthesia. Ischaemia probably assists in increasing anaesthesia in the longer operations. The duration of the operations, Table XLI

Duration of Operation

Time (minutes)	No. of cases
0 - 5	222
6 - 10	36
11 - 15	15
16 - 30	5
31 - 60	4
61 -	2

where intra-arterial injections were successfully carried out, is shown in table XLI. As with the intravenous technique, sensation

/rapidly.....

rapidly returns after release of the cuff. In all, the sensation returned within 5 minutes of releasing the cuff.

Causes of Failure. The failures were all due to a failure of technique - namely, inability to penetrate the artery, blocked needle, displacement of needle from artery, arterial spasm, or combinations of these factors. As ones experience increased, the failure rate fell from 14 in the first 100 cases to 2 in the last 100.

Complications. Short-lived vascular spasm occasionally resulted from repeated unsuccessful attempts at arterial puncture. Haematomas were prevented by pressure for 3 minutes at the site of the injection after removal of the needle. In all cases, pulsating brachial and radial vessels were felt immediately post-operatively and fully palpable pulses were present the day after operation and on subsequent days.

Apart from transient vascular spasm already mentioned, no local complications followed arterial puncture. No toxic reactions due to the anaesthetic solution were observed.

Intra-arterial Analgesia in the Leg

The technique was tried in 3 cases in the lower limb. Here femoral puncture with a wide-bore needle and catheterisation of the femoral artery with a plastic cannula is necessary. The cannula extends beyond a pneumatic cuff placed mid-thigh, and the cuff is inflated once the cannula has been inserted. Local anaesthetic is injected distally to the cuff via the cannula. The first case worked well for 40 minutes but then became ineffective owing to pressure of the cuff falling too low. The other 2 cases failed owing to technical faults. It is not considered justifiable to continue using this method in the leg at this stage.

Intravascular Regional Analgesia - Discussion

Regional analgesia can be induced by an injection of local anaesthetic solution into the arterial or venous side of the vascular system isolated by a tourniquet.

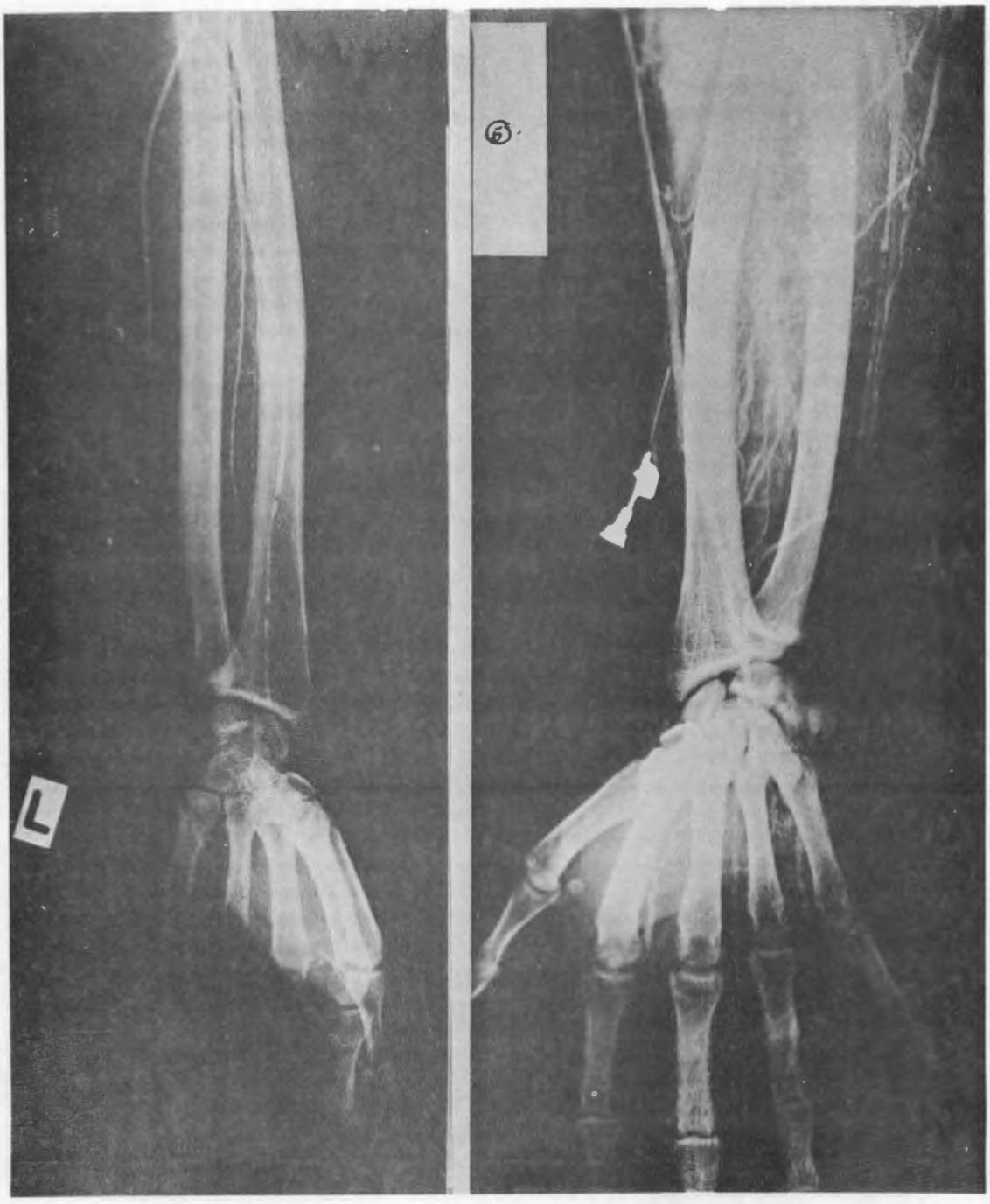
The term 'analgesia' is preferred, for the essential feature of the technique is absence of sensibility to pain. Touch, proprioception and motor function usually persists to a greater or lesser degree.

Mode of Action

In both intravenous and intra-arterial regional analgesia, the local anaesthetic is brought into direct contact with nerve fibres in the nerve trunks and their ramifications and endings by diffusion through the capillaries. In the intravenous technique a large 'venous pool' has first to be filled before the capillaries are filled by retrograde spread. An indication of the extent of the vascular beds which have to be filled before the anaesthetic solution reaches its site of action can be judged by the differences in amounts of anaesthetic solution required - a mean of 14 ml. of 0.5% lignocaine for intra-arterial regional analgesia and 42 ml. for intra-venous. This is illustrated in the cases reflected by fig. 28.

The mode of action of local anaesthetic agents, once the nerve fibres have been reached has been discussed by de Jongh and Wagman (1963). Fibres of small diameter transmitting sensations of pain and temperature are blocked first. The larger fibres transmitting touch, proprioception and motor function, are blocked at a later stage. In an experiment with saline injections, Holmes (1963) showed that analgesia is not an effect of the

/tourniquet.....



(a) (b)

Fig. 28 : Arteriogram (a) and Venogram (b) distal to an occlusive cuff. In both these instances 2% lignocaine was added to 76% 'Urografin' to give a ½% solution of lignocaine. The techniques of intra-arterial on intravenous regional analgesia were done in the usual way and radiographs were taken when analgesia was complete. Volumes of 20 ml. and 60 ml. of the solution were required respectively.

tourniquet nor of anoxia of the tissues, although these do play a small part (Sorbie and Chacha 1965).

The increasing anaesthesia with increasing tourniquet times noted in the present investigation can be explained by the following factors:

1. Persistant diffusion of the local anaesthetic from the capillaries into the tissues, including the nerves.
2. Nerve block produced by prolonged tourniquet compression which blocks the large motor fibres first.

Injections have been made between 2 tourniquets resulting in 'direct' anaesthesia which is immediate and occurs between the cuffs and 'indirect' anaesthesia which is of later onset and occurs beyond the distal cuff (Bier 1910, Sorbie and Chacha 1965). This suggests that nerve endings are affected first and that the large nerve trunks are blocked later.

Redistribution of Local Anaesthetic on Release of Cuff

On release of the cuff, the circulation is re-established and local anaesthetic remaining in the isolated vascular system is flushed into the general circulation. Local anaesthetic which is fixed to the tissues is removed more slowly and it would appear that there is increased tissue fixation with increased tourniquet times (Adams et. al. 1964).

Maximal concentrations in the blood are detected within a minute or two after release of the tourniquet and gradually falling thereafter (Merrifield and Carter 1965). Because of these factors, delayed release of the tourniquet (Morrison 1931, Cox 1964) or intermittent freeing of the tourniquet, (Merrifield and Carter 1965) have been recommended.

/With.....

With few exceptions the operations in the present study were of short duration and the tourniquet was always released without delay.

Toxicity of Local Anaesthetics

Injections of lignocaine have been used without untoward effect in the treatment of cardiac arrhythmias (Weiss 1960), epilepsy (Bernhard and Bohm 1965) for the relief of pain (Gilbert et. al. 1951) and as an adjunct to general anaesthesia (de Clive-Lowe, et al. 1958). The occurrence of toxic effects are however well recognised (Bingham and Malherbe 1957, Deacock and Simpson 1964).

Toxic effects of local anaesthetics can be divided into central and peripheral effects. Cortical stimulation is followed by medullary depression, with resultant cardiovascular and respiratory depression. Large doses of local anaesthetic depress the myocardium directly.

Toxicity is dependent on the total dose of drug administered and its concentration and rate of administration (Sadove et al. 1952). Other important factors are its rate of metabolism and individual idiosyncrasy to it.

Foldes and his co-workers (1960) believed that whatever their route of administration, in the final analysis the toxicity of local anaesthetic agents depends on their plasma concentration. They recorded signs of toxicity at 5.3 micrograms per ml of plasma after intravenous infusion of lignocaine at a rate of 0.5 mg/kg/min for 18 minutes or less. Bromage and Robson (1961) found that toxic symptoms appeared at 10 milligrams per ml. After an intramuscular dose of 3 mg/kg of lignocaine,

/blood.....

blood levels of less than 2 micrograms per ml. were obtained by Sung and Truant (1954). Englesson et al. injected 200 mg. 1% lignocaine intravenously over 2 minutes and 20 seconds and recorded a peak value of 5 micrograms per ml. No serious central nervous system or cardiovascular side effects occurred.

Despite these attempts to relate the toxicity of lignocaine to blood levels, it is believed that the total amount of lignocaine taken up by the vulnerable tissues is the deciding factor and this cannot be measured by blood lignocaine levels. After the release of the cuff, redistribution and uptake are progressive; this is illustrated by one of the cases in the present series in which a seizure took place 10 minutes after the cuff had been released.

Steinhaus (1957) suggested that the minimum dose of lignocaine producing cortical stimulation is 20 - 50% of the minimum lethal dose and that there is a reasonable safety margin. Bernhard and Bohm (1965) discussing the use of lignocaine in the control of epilepsy, showed that raising the injection rate increases the chance of convulsions while the convulsant dose is about 3 times that of the anticonvulsant one. Doses of up to 10 mg/kg per hour may be given to abolish convulsions.

Lignocaine is rapidly metabolised by the normal liver and a small percentage is excreted unaltered (Sung and Truant 1954).

In the present study drowsiness and euphoria were frequently noted and this was regarded as an extension of the pharmacological action of lignocaine. Signs of cortical stimulation were encountered in 8 cases of the present series and were controlled by small doses of intravenous barbiturate (table XLII). All 8 cases received more than 2.5 mg/lb of

/lignocaine.....

lignocaine. No significant cardiovascular or respiratory depression was encountered (one report of a cardiac arrest has been reported in the literature - Kennedy et al. 1965).

Table XLII . Toxic Reactions

Case No.	Type of reaction	%Ligno-caine	Total dose (in mg)	Dose (mg/lb)	Comments
64	Seizure	1	350	3.3	Seizure while cuff still adequately inflated
80	Seizure	0.5	455	3.3	Seizure before cuff deflated
93	Pre-seizure	1	500	3.3	Controlled with i.v. thiopentone
95	Pre-seizure	1	400	2.8	Controlled with i.v. thiopentone
106	Pre-seizure	1	300	2.6	Controlled with i.v. methohexitone
128	Seizure	1	450	3.5	Seizure 10 minutes after cuff deflated
136	Pre-seizure	1	470	3.4	Controlled with i.v. methohexitone
751	Seizure	0.5	350	2.8	Patient had undetected hypertension

Case numbers 64 and 80 deserve comment. There was no doubt in these cases that the cuff was adequately inflated. The likely explanation is that owing to the cuff being situated too low (at the level of the cubital fossa) anaesthetic solution did not disperse adequately and was forced past the cuff into the circulation. When care was subsequently taken to place the cuff well clear of the cubital fossa, no further similar episodes were encountered and the failure rate was reduced.

/Local.....

Local Complications

Monty and Deller (1965) reported 3 cases of superficial venous thrombosis at the site of infection due to lignocaine containing chlor-cresol.

I have observed superficial venous thrombosis in 2 patients. The first patient developed a thrombosis of his forearm veins 3 weeks after surgery to a deep palmar abscess (see fig. 24). In my opinion this was caused by the inflammatory process, rather than the technique.

The second patient developed thrombosis in a vein which was ligated at operation, and in this case the added effects of venous stasis due to the ligation and slight irritation to the vessel wall due to the injection, were probably responsible. No other local complications were encountered.

Safe Dose

Maximum safe dosage of lignocaine with and without a vapopressor has been suggested (Ashworth 1962, Simpson 1963). In 1957 the Scandinavian Pharmacopoeia Council recommended 200 mg. of plain lignocaine and 500 mg. of lignocaine with a vasopressor as safe maximum doses for infiltration and nerve block.

Most authors using intravenous regional analgesia follow the recommendation of Holmes (1963) and give up to 40 ml (200 mg of lignocaine) for an arm and up to 100 ml (500 mg) for a leg in an average adult. Bell and his co-workers (1963) administered doses related to the weight of the patient and recommended a maximum of 100 mg for a man weighing 154 lb. From their study of lignocaine blood levels in the technique of

/intravenous.....

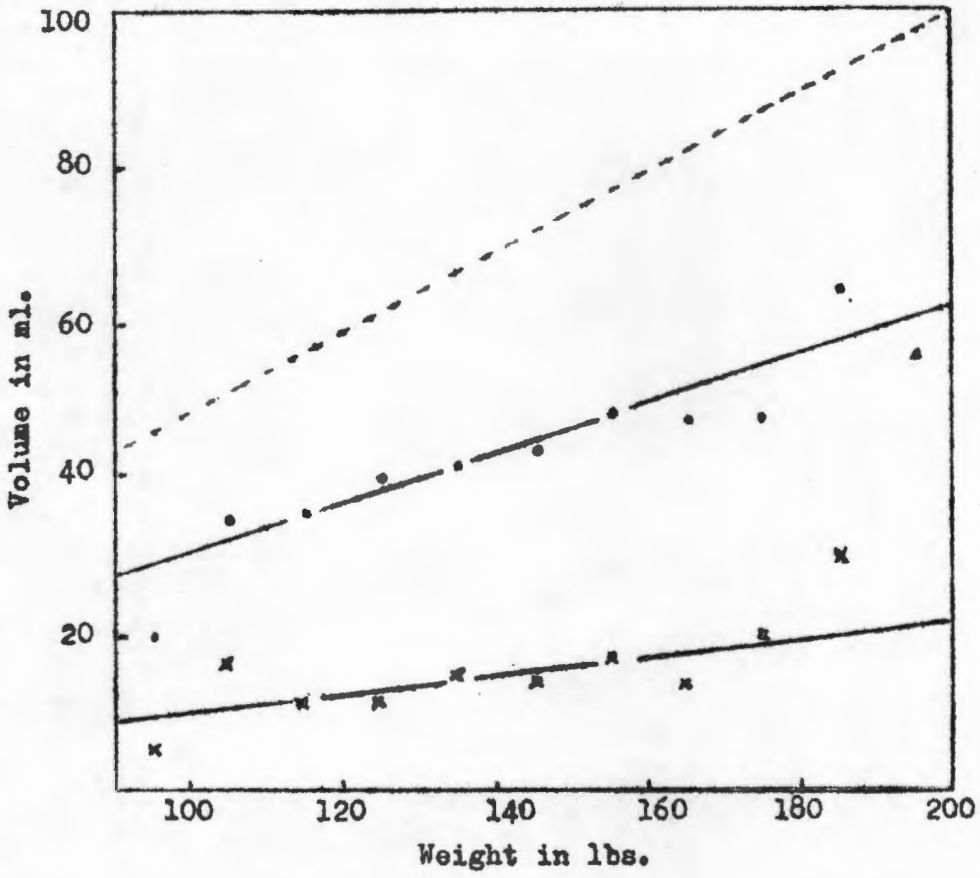
intravenous regional analgesia, Merrifield and Carter (1965) suggested that the dose of 4 mg/kg (1.8 mg/lb) which they found necessary for good analgesia, is safe provided release into the circulation is delayed. Using the technique of intravenous regional analgesia, doses of up to 800 mg have been given by Dawkins et al. (1964) and up to 700 mg have been given in the present series without untoward reactions.

In the present study no toxic phenomena were encountered when doses of not more than 2.5 mg/lb were used, but with higher doses toxic phenomena occurred.

In the group of 803 cases in which isotonic 0.5% lignocaine was used, one patient developed a seizure. This was a case with undetected hypertension in which blood continued to enter the forearm despite the cuff being inflated to 200 mm. Hg. Lignocaine accordingly was excessively diluted with blood, the technique was unsuccessful and the total dose was probably flushed into the circulation on release of the cuff.

The results of the use of isotonic 0.5% lignocaine via the intra-venous and intra-arterial routes in the present study are shown in fig. 29.

Fig. 29 Volume of anaesthetic solution related to weight of patient



Top line - Proposed maximum dose (2.5 mg/lb)

Middle line - Mean volumes - intravenous regional analgesia (1.6 mg/lb)

Lower line - Mean volumes - intra-arterial regional analgesia (0.52 mg/lb)

Proposed Modification of the Intravenous Regional Analgesia Technique

Reports on the intravenous method of regional analgesia indicate that the main drawback is a relatively high percentage of failures when standard dosage schedules are used and of toxic phenomena when these are exceeded.

The dose of lignocaine may be reduced by the following devices:

1. Complete exsanguination of the arm.

/Prolonged.....

2. Prolonged tourniquet time prior to injection of local anaesthetic.

3. Delay in operation after injection, which allows maximal effect of the anaesthetic solution to take place.

4. Use of intra-arterial injection rather than intravenous.

The uptake of anaesthetic solution in the general circulation may be reduced or slowed by:

1. Washing out of the local anaesthetic prior to release of the cuff.

2. Prolonged tourniquet time (increasing local fixation of lignocaine).

3. Intermittent release of the cuff.

Further important points are the use of the lowest effective concentration and the smallest effective volume of anaesthetic.

In the present series exsanguination could not be used because of the infections; washing out of the local anaesthetic was tried but did not work to any extent, while other points detract from the quickness and simplicity of the procedure.

Results of the present study show that toxic phenomena were not encountered in patients receiving up to 2.5 mg/lb of lignocaine. In the intravenous technique, with isotonic 0.5% lignocaine, 52 cases (6.5%) received more than this amount, yet only one patient showed toxic features and this was due to poor technique.

The following modification of the technique as described earlier is therefore suggested. Each patient receives up to 2.5 mg/lb of isotonic 0.5% lignocaine (this also has the merit of

/being.....

being easy to calculate - half the patients weight in lb is given in ml of anaesthetic solution). If analgesia is not effective with this dose, a 'chaser' of normal saline is given until analgesia is established. Usually 20 - 40 ml of additional saline will suffice, but up to 60 ml have been required. (It is considered that these suggested doses should also not be exceeded for surgery of the leg).

This modification has been used in a further 420 cases of septic hands operated on up to the end of November 1965. All were successful and no further toxic reactions were encountered.

SUMMARY AND CONCLUSIONS

Clinical experience with intravascular regional analgesia in some 1,700 cases is discussed.

A new method of regional analgesia by intra-arterial injection of local anaesthetic is described.

The use of intravenous regional analgesia in hand infections is described and a modification of the technique is proposed. It is believed that with attention to the details of the technique and with the use of the proposed method uniform success with no toxic reactions can be achieved.

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