An Address ON FLAIL JOINTS AND THEIR TREATMENT.

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ONE of the common products of the results of war injuries is the flail joint; in other words, a pseudarthrosis which is of very imperfect function, because the bones forming it do not come in contact, and, in consequence, the lever is imperfect because it has no fulcrum. The greater number of these disabilities are the direct results of excisions deliberately performed at casualty clearing stations or base hospitals. They were performed in order to save the limb from amputation, or the patient from death by minimizing local sepsis and preventing general sepsis. Joints are difficult to drain, and the excision simplified the immediate problem. The only competent judges of the necessity of these measures were the surgeons at the front, upon whom rested so many grave responsibilities. It is our duty to recognize this, and to try to make suggestions for the immediate and later treatment of these loose joints in order to minimize the loss of function.

It is well, however, to realize, as judged from cases which have arrived at our centres, that upon the type of resection largely depends good or bad function. Cases of so-called limited resection have resulted in better function than where the excision has been extensive. Furthermore, cases in which the sepsis has been overcome and the bones allowed to remain in position have resulted usually in very good and firm ankylosis with excellent function if the position of election has been maintained. There is no reason why any joint should be allowed to heal at functional disadvantage. This, however, is even yet not sufficiently appreciated. I draw attention to this, not as a matter of adverse criticism, but in case one may be tempted sometimes to excise too much bone, or to forget that many most excellent results are chronicled where excision has not been resorted to.

The flail joint may follow—

- (a) As a direct result of excision.
- (b) The removal of large comminuted masses of bone.
- (c) The direct loss of bone from missile.
- (d) The extrusion of necrosed bone during sepsis.

METHODS OF PREVENTION.

In considering the prevention of flail joints we have to bear three principles in mind: (a) The extent of excision should be strictly limited, subject only to conditions of safety; (b) the extension applied should be very moderate; and (c) ankylosis should be aimed at rather than mobility.

(a) *The Limitation of Extent of Excision.*

This is very important. Muscular attachments which have important influence in maintaining good function should be spared where possible. The tuberosities of the humerus, the nerve supply of the deltoid, the condylar attachments of the muscles governing the elbow, the triceps expansion, the biceps insertion, the coronoid, and, if possible, the whole or a portion of the olecranon should be preserved.

Again, we should endeavour to retain as much width of the lower end of the humerus as is possible, in order to allow the surgeon to restore leverage later.

If it be impossible to leave the important muscular attachments *in situ*, it may be possible to chisel off the portion of bones to which the muscles are inserted—such as the olecranon, tubercle of radius, coronoid process, and the tuberosities of the humerus.

(b) *Extension should be Moderate.*

We should strictly limit extension both in extent and time. I have seen several cases in which after excision of elbow a Thomas arm splint has been applied for three months and more with separation of the joint surfaces for many inches. The extension should be strictly limited to

the urgent needs of drainage. Strong extension of a limb where the joint has been excised obstructs free drainage. The extension, if necessary at all, should be of the lightest kind and maintained for the shortest period possible. An abducted shoulder and a flexed elbow admit of excellent drainage. In the case of the shoulder and of the elbow the dependent position of the arm and forearm permits of pus tracking down the muscular planes.

(c) *Ankylosis.*

The rule should be to aim for ankylosis in the best position for function. We need not again enter into the arguments for and against mobility. The fact that we aim for ankylosis does not mean we shall attain it. We very rarely can, but the effort leaves us the best possible result for future reconstruction. The rule, therefore, for the surgeon at the front should be that so soon as possible he should place the bones as near together as he can, and in the best position for future function, whether pseudarthrosis or ankylosis occur.

TREATMENT OF THE FLAIL JOINT.

The flail joint as we meet it is practically useless from the point of view of function, and it demands mechanical or operative treatment or a combination of both.

Treatment may consist of (a) removal of necrotic bone and scar tissue, (b) postural treatment, (c) operative attempts at improved pseudarthrosis, (d) production of ankylosis, (e) retention in mechanical apparatus.

(a) *Excision of Sinuses, Scars, and Infected Bone.*

A fair proportion of flail joints—especially the shoulder—are infected and discharging. Where it is possible they should be treated as in the case of osteomyelitis elsewhere, by excision of sinuses, scars, and infected bone. Whether operated upon or not, the bone surfaces should be approximated and retained in the functional position. A proportion of cases take in their slack and ankylose, or a much firmer pseudarthrosis results. The shoulder and elbow are the joints most responsive to this treatment.

(b) *Postural Treatment.*

When all wounds are healed the shoulder should be placed in the functional position either by means of an abduction splint or an angular elbow splint or in plaster. The latter method lends itself very well to these two joints, and gives the much needed stability. The bones should be insinuated into juxtaposition to each other without crumpling the soft tissue between them. Immobility should be secured for at least three months.

If the muscles governing the joint retain power, the after-treatment must be carefully conducted. In the shoulder the upper portion of the plaster support should be removed, so that the arm rests on the gutter-shaped under part of the case. The patient should be allowed liberty to exercise his deltoid, and when he can lift it slightly from the case the arm can be brought a little nearer to the side and fixed in an abduction splint whose angle has been lessened, and a larger range of movement may be allowed to the scapula and humerus. The arm is still further lowered until it can be safely dropped to the side.

If the pseudarthrosis is bony or short fibrous, the shoulder blade becomes the joint. If there is free mobility, the deltoid may be trained to lift the arm. This it does by raising the lower fragment and drawing it against the axilla, the result being quite a useful functioning joint. The elbow, when it is removed from the sling, should be more acutely flexed, and the forearm slung by the wrist, in order to strengthen the biceps and brachialis anticus. As these muscles gain in power the forearm can be gradually lowered until it reaches a right angle. For a considerable time it should be kept from further extending, in order to retain the power gained by the flexor muscles. Such shoulders and elbows, however, are always weak, and in the elbow a considerable lateral instability results. A hinged splint with a shoulder cap will be of advantage in the case of the unstable elbow.

(c) *Operation to Improve Pseudarthrosis.*

Attempts may be made at improving the stability of weak pseudarthrosis by operation. This should only be attempted when the muscles governing the joints may be reasonably expected to recover strength. The operation

consists in removing intervening scar tissue and bringing the bone into contact. They may be kept together by means of kangaroo tendon or other absorbable material. In the case of the humerus a bone graft may be used to lengthen the shaft, but we will discuss the position of bone grafting later.

(d) ANKYLOSIS.

Ankylosis of the flail joint, often a difficult matter, will be discussed in relation to the joints involved.

Flail Hip.

If the femur has merely been deprived of the head and neck all that is needed is to correct any deformity which obstructs walking—such as adduction. This can be done by division of the adductors. If the limb cannot bear weight a jointed calliper splint should be applied. This supplies an artificial lever, and the muscles governing flexion resume more of their function. With such a splint the patient can walk long distances with ease and strength. When the trochanter and part of the shaft are also lost this splint proves very useful. Bone grafting, as usually understood, is of no use in the upper part of the femur. Ankylosis in the case of limited excision of the hip is of no advantage, and certainly does not justify the severe operation which it would necessarily entail. If the trochanter and part of the shaft has been removed, the most likely method of obtaining ankylosis is to take a long strip of femur half its thickness and slide it into a prepared acetabulum. The slide should rest for two or three inches in the groove of the femur. Such a graft has a much better chance of life than when introduced from another part of the body. A thin graft removed from elsewhere never develops strength in the adult and will refracture.

Knee.

Ankylosis of this joint is the only practical treatment, and if the bones are in good condition nothing is needed excepting to saw the ends and fix with screw or nail. If there is wide separation, however, and the ends have been associated with sinuses, union is not easily secured. In such a case it will be necessary, after sawing the ends of the bone, to bring a bulky sliding graft from tibia or femur and wedge it in at right angles to the line of the joint. This is a method I have often employed in secondary excisions where union has not been firm. If there is shortening to the extent of many inches the patient may prefer an artificial limb, and he may supply arguments worthy the surgeon's consideration. If an operation is refused, the calliper splint and a high boot will afford the best help.

Ankle.

Flail ankle is so rare that I cannot recall an instance as the result of a war wound. Should it be met with, the treatment will lie between an ankylosis or an amputation.

Flail Shoulder.

I have already described the postural treatment of flail joint, and have mentioned that a successful pseudoarthrosis does not often occur in the case of the shoulder. In a limited number of cases where the head of the bone only has been removed, and where the muscles attached to the tuberosities and the deltoid are functioning, abduction and carefully conducted muscle re-education may result in a joint preferred by some people to an ankylosis. The very flail joint can only be approached with confidence if an ankylosis be aimed at. I have seen certain cases where a graft of bone has been introduced to lengthen the shaft—in one case the upper part of the fibula—with results which I would call promising. I have also seen cases in which these grafts have refractured (they never unite again), and others in which they have been absorbed, leaving the patient in a worse plight than before. The result of my experience is that I would prefer adopting a more certain route, such as the production of ankylosis by end-to-end apposition.

Captain Platt has described a method of bone transplant which may still be considered under trial. It is an attempted reconstruction of the head of the humerus in order to obtain a fulcrum for scapular movement. He takes a large autogenous graft from the tibia, shaped like a wooden mallet. The shoulder-joint is exposed, the upper

end of the humerus cleared, and the handle of the graft driven into the medullary cavity. The wide upper end is now brought into contact with the glenoid cavity, which has been completely bared as in an ordinary arthrodesis operation. On occasions he has used a long fascia lata sling carried through the upper end of the humerus, the upper margin of the glenoid, and the acromion process. After completion of the operation the arm is placed in abduction until stability is secured.

Many operations for fixing the shoulder have failed because the surgeon has been content to bare the glenoid and freshen the humerus. This is usually insufficient. If the deltoid has been hopelessly deprived of function, an excellent exposure can be obtained by turning back a flap of skin and exposing the upper part of the deltoid; this muscle can be cut across or reflected upwards as a flap. The joint is fully exposed, and the glenoid can be gouged as deeply as possible. The base of the coracoid and the acromion should be chiselled, and the bony flaps left attached. The upper part of the humerus should be exposed and sawn through, and a groove made into the upper part of the shaft for the reception of the acromion. The humerus is pushed into the glenoid and the acromion sawn through and received into the groove prepared for it. The glenoid, humerus, and acromion should be fixed in contact by kangaroo tendon and placed in the functional position.

Major Naughton Dunn has pointed out to me that if there be much shortening of the humerus the functional position will vary from that which I have advocated. If there is no loss of bone the position of selection is just in front of the coronal plane of the body, while if there is much loss of bone it will be necessary to fix it in a plane posterior to this, otherwise in flexion of the elbow the hand will pass beyond the mouth. It is advisable before fixing the shoulder to test the position by flexing the elbow and observing the function. Dunn has described the operation he performs; it is very similar to that already mentioned. He makes an anterior incision, freshens and exposes the upper end of the humerus by removal of the sclerosed ends in one or two positions. These fragments of bone are retained with their blood supply intact to form new attachments and help to strengthen the arthrodesis. The under surface of the acromion is removed by a gouge from without inwards to opposite the upper margin of the glenoid cavity. This partially detached piece of bone is then folded into the space between the under surface of the clavicle and the upper margin of the glenoid cavity. The acromion process is divided about one inch from its extremity so that it may be brought into direct apposition with a prepared surface on the shaft of the humerus. The prepared shaft of the humerus is impacted into the glenoid cavity and maintained there by suture.

After all operations to obtain ankylosis the arm should be immobilized for three months.

Before the arm is ankylosed care should be taken to ascertain whether the scapula is mobile, also whether it retains its normal position in regard to the humerus. This is extremely important. The success of the operation depends on sound ankylosis and a mobile scapula. If the scapula is fixed the result of the operation is a tragedy, as the patient has a fixed abducted shoulder which he cannot lower. I have seen several such results.

After operation great care should be taken to exercise and re-educate the scapular muscles. The range of scapular movement in the young soldier increases for many months.

Flail Elbow.

Two methods of treatment are available here: (a) the non-operative, and (b) the operative. How can we predict the case in which it is impossible to bring about stability without operation?

The non-operative method consists of the approximation of the bone ends, counteracting the effect of gravity, and in muscle re-education and development. It also often involves the wearing of apparatus.

The operative treatment has one of two ends: (a) the formation of a bony ankylosis, or (b) the provision of a mobile arm with stability.

The non-operative treatment is only likely to be successful where the bone ends are broad. If the bone ends are pointed and distant, non-operative treatment cannot be successful even with good muscular control.

Ankylosis of the Elbow.

Many surgeons have described how difficult it is to obtain union in flail elbows. Failure is probably due to a technique which trusts too much to limited surfaces of attachment. There is so little vitality in the ends of the bones that a mere freshening with apposition and fixation will often fail to accomplish union. When nails are driven in the result is no better and further interference with blood supply is threatened.

The operation to be desired is one whereby a larger apposition of raw surface is secured. This can be effected at times by splitting the ends of the bones, and in this way widening them. Naughton Dunn has described to me the scheme he adopts with results I know to be satisfactory. He makes a subperiosteal exposure of the fragments to within an inch of their extremity, and completes this exposure by partially detaching a portion of bone triangular in shape from each side of the extremity of the shafts of the humerus, radius, and ulna, leaving them anchored by periosteum. This permits of an enlarged area of bone apposition and more productive osteogenesis.

Several such operations are practised with variations in detail. The principle remains that pieces of bone should be so arranged as to allow of good apposition.

Pseudarthrosis of the Elbow.

We need not now discuss pseudarthrosis of the elbow when this operation is performed for mobilizing an ankylosis. It is a different proposition when we wish to stabilize a flail joint and yet permit of voluntary movement. A necessary condition to the success of this operation is a sound muscular control. If this is not present the operation should never be performed.

Captain McMurray has had a successful series of cases by employing a scheme the object of which is to secure movement with improved lateral stability. A vertical incision is made over the posterior aspect of the joint of a length varying with the amount of bone missing, and extending about 2½ in. over the upper end of the ulna and the lower end of the humerus.

The lower end of the humerus is completely cleared from the overlying tissues for a distance of 2 in. The upper end of the radius and ulna are likewise cleared completely to the level of the orbicular ligament.

It is generally found that the olecranon has been removed at the time of wound or operation, and if this be so the lower end of the humerus is made into the shape of a wedge by removing bone laterally, thus—

A wedge of bone is removed from the neighbouring sides of the radius and ulna, as shown above; this wedge is larger in extent than is necessary to contain the wedged lower end of the humerus. A flap of fascia is now prepared for placing round the lower end of the humerus to prevent any adhesions between the bones. This flap may be taken from the tissues in the neighbourhood, if these have not been destroyed, or it may be taken from the fascia lata of the thigh. The question whether this flap is free or pedunculated does not seem to be of any importance as both act equally well. Whichever flap is taken is sutured in position round the lower end of the humerus, which is then placed deep into the space between the upper end of the radius and ulna so that the ends of these bones project behind the humerus. A drill is then passed through the three bones in this position, and the relative position of the bone maintained by means of kangaroo tendon. If the triceps has lost its attachment to the upper end of the ulna, it is now freed from adhesions and attached securely to the upper end of the bone.

If the olecranon is present at the time of operation the wedge from the radius and ulna is taken at the same spot as before and the olecranon is left projecting back from the humerus—so increasing the power of the leverage which is obtained at the elbow-joint.

The arm is fixed in abduction, and voluntary movements encouraged after three weeks. After eight weeks

the arm is allowed down by the side, and the tendency to stretching of the biceps is prevented by the wearing of a sling.

In order to render the joint less flail Captain Platt has devised an operation which consists essentially of binding the bone ends together by strips of fascia lata. After exposure and removal of scar tissue he drills the lower end of the humerus and the upper ends of the radius and ulna, and the artificial ligaments are carried through in planes at right angles to each other and tied securely—the knots being fixed by sutures—and the ends of the ligaments are then fixed to the remains of the joint capsule and the muscle insertions in this region. The limb is slung up in 40 degrees flexion, and muscle education is begun at an early stage. The training is begun in the position of abduction of the shoulder. The stability of the elbow is considerably improved by the operation.

The final results in these cases are very promising. Pronation and supination are lost, but, at a later date, if the ankylosis is firm, operation may be undertaken with a view of restoring this movement. This operation, practised by McMurray, is successful. The bony expansions of the V incision into radius and ulna prevent lateral mobility. If the operation fails an ankylosis in good position may be expected.

Flail Wrist.

This is so rare that I need only say that ankylosis should be performed if thereby function is likely to improve.

In attempting to produce ankylosis of any flail joints we often succeed in producing a satisfactory pseudarthrosis. When we directly aim at a pseudarthrosis we are in danger of losing stability.

STIFF JOINTS.

The stiff joints following injuries of war have to be approached with greater respect than in the case of those we met with in pre-war days. Latent sepsis so often present is almost a new phenomenon. The stiffness due to immobilization is far more intractable.

Extension of the Knee.

A fracture of the femur in pre-war days, either simple or compound, retained in a Thomas splint used to leave the knee-joint only temporarily stiff; a fortnight of massage and gentle movement was sufficient to restore mobility. This is not the case in fractures we are now dealing with, for the rigidity is much more pronounced, and a longer time is required to overcome it. Recent improvements in the Thomas splint, and the introduction of the calliper ice tong extension, make it quite unnecessary to keep the knee immobile for months, so that in future we should not have to face the problem of extreme rigidity. I will not deal now with the ordinary light periarticular adhesions which require only simple handling.

Gradual Flexion of the Knee.

Rigidity is sometimes so marked that surgeons have failed to make any impression upon it by attempts at forcible flexion—a procedure of doubtful wisdom and often very hazardous. Such cases will often yield to the influence of gravity and gradual pressure. A long posterior splint is applied, bent to an angle of 15 degrees. The extended limb is bandaged to this, and when the knee yields sufficiently to rest upon the splint it is allowed to remain there in order to permit the strained tissues to calm down. The bandage is then removed from below the knee and voluntary efforts are allowed towards extension. When this is secured, and not until then, the splint is bent a few more degrees, and the procedure is repeated. This plan is continued until sufficient flexion is obtained to enable the joint to be more vigorously exercised first by active and then by passive movements. Before this is done there must be assured the power of full voluntary extension. If the knee becomes firmly fixed in its new angle of flexion it is sufficient proof that this method of attack is premature or useless. In certain cases under anaesthesia a limited flexion can be recovered, but any attempt at increasing this is so resisted by firm tissue that the surgeon has to desist. If such a limb is fixed by splint or plaster in the newly gained position, and kept fixed for a week or so, a further gain can often be secured under anaesthesia on a second occasion. This can be repeated until a fair range

of movement is acquired. The fixation of resisting tissue under strain renders such tissue less obstructive. A recognition of this fact will prove very helpful to us in dealing with obstinate stiffness.

If when flexion is obtained in this way the limb remains firmly flexed and resists attempts at extension, we are not making progress. If on extending it again it becomes rigid in extension after reasonable rest, we may be sure that we are being met by tissues which undergo reaction of a type that does not admit of further force.

When strong periarticular adhesions are thus stretched, a certain transient degree of stiffness in the new position will occur, but after a short course of massage and voluntary effort this will disappear. The advantage of gradual stretching over rapid tearing is that haemorrhage and excessive inflammatory reaction are avoided. There is a still further and very vital reason why excessive force should not be applied; instances have happened in which the patella tendon has been torn or the patella fractured, and I have met also with cases in which the quadriceps has been ruptured.

I am convinced that in injuries of the knee, directly or indirectly resulting from war missiles, forcible manipulation has only a very limited field for application. It should be confined to the lighter type of so-called periarticular adhesions; and, as I have suggested, in the more rigid type of case the aim should be, if anaesthesia be employed, to obtain only a few degrees of movement in successive stages, with intervals of complete rest.

Operation.

Surgical intervention may be necessary in cases of (a) muscular adhesions to bone; (b) scarring and shortening of capsule; (c) intra-articular adhesions due to arthritis or fracture; (d) fixed patella; (e) bony ankylosis of femur and tibia.

Muscular Adhesions.

Muscular adhesions interfering with flexion are generally associated with the quadriceps. If the muscle is firmly bound down, the rigidity of the knee is very marked. These are the cases in which surgeons point out that after forcing the knee they have gained a slight degree of movement. If the knee is examined, however, it will be found that they have either lengthened the patellar ligament or sometimes ruptured it, and, although the knee will bend a few degrees, it cannot be voluntarily extended. These cases should never be subjected to forcible movement. They have often been associated with a compound fracture, or suppuration in muscle sheaths, or with osteomyelitis.

The operative treatment for adhesions of quadriceps is to detach the muscle from its adhesions, and to place a living flap of fat and fascia between it and the bone. The knee should be kept flexed during healing and the muscle subjected to electric stimulation.

Certain cases have suffered losses in muscle structure which have resulted in shortening, and operative elongation should be considered.

Shortening of Capsule.

The x-ray picture in a case with shortening of the capsule may exhibit a perfectly normal joint, and the patella be fairly free. There is no undue tension of the ligamentum patellae, the quadriceps is not adherent, and yet the knee is firmly rigid. With these symptoms we can safely make a diagnosis of tense or contracted capsule. This should be treated first of all on the lines laid down in regard to severe periarticular adhesions, and if the rigidity still persists operative interference may be called for.

Operation.—A curved incision should be made from the femoral attachments of the internal lateral ligaments to the tubercle of the patella. The capsule is exposed, and a curved incision made in it, extending from the anterior aspect of the ligament. The patellar tendon need not be divided if it does not obstruct; if it does it can be elongated. The operation is simple, and should involve no risk.

Intra-articular adhesions are treated by gradual flexion under careful observation. If signs of severe inflammatory reaction should appear, treatment by this method should cease. A little pain and some effusion need not interfere with the stretching. Severe pain, with rise of temperature and effusion, should warn us of trouble.

Adhesion of Patella to Bone.—The patella is sometimes bound down by adhesions to the femur, and this alone will cause fixation of the knee. If the adhesions are light they will sometimes yield to manipulation and exercise; if not, the bones may be freed by operation. Where the attachment is bony, separation may be effected by chisel, and a flap of fascia, or the bursa of the patella, introduced between the bones. If the attachment is extensive and rugged the bones should be slightly excavated and made smooth. Horsley's wax can be rubbed into the femoral erosion, and the bursa laid upon the surface of the patella.

Complete Ankylosis.—If ankylosis is complete and the bones are in good position no surgical interference is needed.

Arthroplasty.—In my opinion, arthroplasty of the knee has no place in military surgery. Cases have been met with in which a gunshot wound, not complicated by sepsis, has caused very limited ankylosis. Such conditions can be operated upon with advantage if the joint is otherwise healthy. It is better not to introduce flaps of tissue; but, after chiselling through the obstruction, to excavate the attachments, making them saucer-shaped, rubbing in Horsley's wax as recommended by Stiles, and if possible keeping the knee in any position whereby the raw surfaces are least in contact. Ankylosis may occur, however, in bad position. This may present flexion deformity, lateral deviation, genu recurvatum, or a combination of all these.

Flexion of the Knee.

If the knee is flexed and sound and painless, with no more than 30 degrees of flexion, it is best to leave it alone. If the flexion exceeds that, an operation may be considered, but the advantages and disadvantages should be fully discussed with the patient.

Operation.—A wedge of bone should be removed from the front of the knee, so that when the bones are wedged together firmly the knee should remain at an angle of about 15 degrees.

I have always advised placing the knee-joint fully extended while we wait for an ankylosis to occur in inflammatory conditions, and also where we have to perform a classical excision. To keep such knees in a slight degree of flexion is often difficult and jeopardizes firm union. When, however, we excise a wedge, these difficulties do not arise, and an angle of 15 or 20 degrees gives a very useful limb from the point of view of function. Supracondylar osteotomy, unless planned to avoid recrudescence of sepsis, is inadvisable, as the result is never so artistic, more especially if the flexion is marked.

Lateral deviation should be treated as in a case of genu valgum by supracondylar osteotomy.

Genu Recurvatum.

This is best treated by supracondylar osteotomy. It is not necessary to remove a wedge. Great care should be taken to prevent sagging at the site of incision. The success of this operation depends entirely upon keeping the femur bowed forwards at the site of the osteotomy incision. After excision and osteotomy a calliper splint should be worn for three months.

We must remember that sound bony ankylosis in a good position is much more useful than an unsound ankylosis with limited and painful movement. Such an unsound ankylosis often has to be transformed into bony fixation. Bone grafting, although it may be useful in fixing a flail joint, is never needed as an accessory to completing the fixation of a painful fibrous flexed ankylosis. Stability of the knee yields better function than a flail pseudarthrosis.

SOME experiments reported to the American Chemical Society by Hirschfelder, Lang, and Feaman showed that the smoke coming from a given weight of tobacco in a cigar, cigarette, or pipe varied somewhat, but not very greatly, in its poisonous action on frogs. When the same weight of the same sample of tobacco was smoked as a cigar, in a pipe, or as a cigarette there was very little difference in the poisonous quality of the smoke, but usually that from the cigarette was less poisonous. This is attributed to the fact that much more tobacco is being converted into smoke in a given time in a pipe or cigar than in a cigarette. The burning occurs chiefly at the surface, and cigars have about four times the cross section of cigarettes, and pipes may have ten times. Cigarette smoking, if the smoker does not inhale, is the lightest form of tobacco smoking.