DRAINAGE OF THE BLADDER WITH SPECIAL REFERENCE TO URETHROSTOMY

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The objects of this article are threefold ; firstly, to discuss the methods of bladder drainage now in common use, secondly, to give an account of the writer's personal experience of drainage of the bladder by urethrostomy and thirdly, to evaluate the various procedures and to determine, in the light of present knowledge, under what circumstances they should be employed.

The history of surgical drainage of the bladder is a relatively short one and, although temporary relief of the acutely distended viscus by catheterization or by perineal puncture had been practised since the remotest times, it was only towards the end of the last century that planned drainage of the bladder in the more chronic forms of retention began to be employed. In his 'Clinical Lectures on Diseases of the Urinary Organs' (1879), Sir Henry Thompson described his new method of permanent suprapubic drainage in cases of chronic prostatic obstruction, a method which he had employed in five of his patients during the previous ten years. This is the earliest description the author can find of the planned use of a flexible tube to serve as a permanent outlet for the urine from the bladder although intermittent suprapubic drainage by the trocar and cannula method appears to have been employed for some time before this by Thomas Paget and others. Thompson's method, which is noteworthy for its ingenuity in avoiding injury to the peritoneum and for the ease and safety with which it could be performed, consisted of the passage into the bladder of a large hollow metal sound with a well-marked curve, its obturated end being made to project anteriorly just above the symphysis pubis. A small incision was then made through the linea alba and the anterior wall of the bladder so as to expose the point of the sound, and the end of the instrument was made to protrude into the wound. On removal of the stylet the flexible suprapubic tube was threaded into the lumen of the sound. Withdrawal of the latter along the urethra then guided the tube into the bladder and thus provided a watertight outlet. A suprapubic operation such as this must have been a revolutionary change for one whose routine approach to the bladder had always been through the perineum,

but as the operation was adopted only as a last resource in patients whose fate was already more or less sealed by the effects of prolonged catheterization, it is not surprising to learn that the period of survival in these earlier cases of suprapubic cystostomy averaged only a few weeks. Soon it became recognized, however, that only by drainage of the obstructed bladder at a much earlier stage could a reasonable prolongation of life be expected and it was not long before suprapubic cystostomy came to be adopted as a standard procedure whenever the urethra was no longer a practicable channel for the passage of urine.

Harrison's description of bladder drainage by urethrostomy in cases of stricture also appeared at this time (1878) and will be referred to later. Shortly afterwards, Freyer and other early prostatectomists introduced the wide-bore tube for post-operative drainage of the bladder. This may well have constituted a more important advance than the actual removal of the prostate gland because it enabled suprapubic operations on the bladder to be undertaken safely for the first time.

Efficient drainage must still be regarded as the first line of defence against the three serious complications which may follow any operation on the bladder, namely haemorrhage, infection and urinary extravasation. Improved methods of haemostasis and the chemotherapeutic control of urinary infections may allow risks to be taken with the first two but failure on the part of the surgeon to give good drainage whilst the bladder heals remains fraught with the gravest consequences. Extravasation into the paravesical cellular tissues will always delay healing ; it may form a urinary fistula and, if cellulitis develops, may seriously threaten the patient's life.

One of the main problems facing the surgeon who carries out immediate closure of the bladder after prostatectomy is that of satisfactory bladder drainage. Post-operative extravasation of urine is the most important local cause of the mortality and morbidity of 'closed' operations and unless

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it is eliminated there is a real danger that this method will, in the long run, prove to be a step backwards in prostatic surgery.

The presence of a tube of some sort to drain the bladder post-operatively then must be an accepted principle of bladder surgery, but it should also be recognized that this arrangement will facilitate the entry of bacteria into the urinary tract. The inevitability of post-operative tube infection has been emphasized by Rathbun (1934), Deming (1947) and Galbraith (1948), although Wilson Hay (1945) claims to have largely abolished it by his retrograde method of catheterization and the avoidance of pre-operative instrumentation. The term 'aseptic' prostatectomy, however, implies a sterile urine during the post-operative period but until accurate details of bacteriological examinations of the urine of such patients are available this can only be regarded as the expression of an ideal and not as an established scientific fact.

The methods of bladder drainage may be conveniently grouped under three headings; firstly drainage of the obstructed bladder, secondly drainage of the paralysed bladder and thirdly post-operative drainage. In the first and second groups temporary or permanent drainage may be required.

Methods of bladder drainage to be considered are (i) Perineal, (ii) Suprapubic, (iii) Catheter and (iv) Urethrostomy.

Whatever the method used the surgeon's task is by no means finished when a tube has been inserted into the bladder in the operating theatre. Close supervision of the actual collection of the urine is necessary in order to prevent contamination of the end of the catheter or tube by the bed-clothes when the patient is returned to the ward. Dukes (1920), who studied urinary infections after excision of the rectum, states that it is usual to find the bladder urine teeming with bacteria on the second or third day after the institution of the 'wooden peg' method of intermittent catheter drainage. To avoid this contamination he evolved the St. Mark's apparatus, a manually controlled system of free drainage and irrigation of the bladder, which not only greatly reduced the incidence of these infections but, when they did occur, minimized their severity. Closed methods of bladder drainage on similar lines to the St. Mark's apparatus have been universally adopted because they are simple, effective and almost fool-proof. The experience gained in the treatment of paralysed bladders during the second World War showed that the advantages claimed for tidal drainage, especially as regards the maintenance of positive intravesical pressure, are more theoretical than real. In a series of 61 cases of spinal cord injuries Prather (1947) found that pro-

longed free drainage by any of the closed methods did not appreciably delay the return of bladder function.

Measures to prevent the spread of infection along the outside of the catheter or tube (by antiseptic dressings around the glans penis, prevention of excessive movement of tube or catheter, etc.), are details of nursing which must be strictly enforced.

It is now becoming increasingly apparent that haematuria, renal failure and many of the other serious consequences of emptying the chronically distended bladder are due, not to purely mechanical causes as was formerly thought, but to infection introduced by tube or catheter. Hence the present tendency is to abandon the various methods of slow decompression and to concentrate instead on free drainage with chemotherapy and other measures to control infection.

(i) *Perineal drainage* of the bladder is a method now only used to any great extent by the perineal prostatectomist. The author's experience of perineal prostatectomy is limited to a series of 30 cases operated on during 1937-9. At the time he was most impressed by the smoother convalescence and by the lessened incidence of urinary infections and other complications as compared with suprapubic methods and it was felt that the difference could only be accounted for by dependent perineal drainage. Unfortunately this advantage was sometimes more than offset by the unavoidable damage to the perineal muscles at operation; moreover it was found that late cicatrization along the track of the tube could give rise to most formidable post-prostatectomy obstruction.

The mortality rate of perineal prostatectomy should always be lower than that of methods which involve an abdominal incision, but the mere possibility of such serious sequelae as permanent incontinence and stricture formation imposes, in the writer's opinion, so severe a handicap on this operation that it can only be justified in exceptional circumstances. The fact that the perineal route, despite its crudeness and its many obvious drawbacks, had been used for all operations on the bladder, such as lithotomy, bladder-puncture for retention, etc., long before the birth of Hippocrates and was still being advocated by Thompson in a standard British textbook as a routine procedure as recently as 1878, could only be due to the better results achieved by that method. We know that the far simpler suprapubic removal of calculi ('high' operation) was described by Pierre Franco in the 16th century, but it seems obvious that, in the absence of any drainage tube, the dependent position of a perineal wound would have overwhelming advantages.

Perineal cystotomy was quickly discarded when the suprapubic tube was introduced at the end of the last century, but the incidence of prevesical cellulitis appears to have been high at first, due chiefly to inadequate precautions against leakage of urine from the low cystotomy wound. Freyer (1908) laid down that water-tight suturing of the bladder wound around a large suprapubic tube was one of the essentials to success after his method of prostatectomy. Later, Lynn-Thomas (1914), impressed by the advantages of free bladder drainage, added counter-drainage in the perineum. By his 'combined' method of prostatectomy a perineal drain was introduced from below by cutting down on the point of a forceps thrust down through the prostatic cavity after performing a suprapubic enucleation of the gland. Fullerton (1913) also practised the combined method of prostatectomy and stated that added safety was conferred on the suprapubic operation by dependent perineal drainage. In one of his cases incontinence of urine developed 'as the result of prolonged pressure by the perineal tube' and it must be presumed that this method was quickly abandoned when the possibility of this complication was realized.

From the anatomical point of view then, perineal drainage of the bladder is the ideal method. Unfortunately its practical value is limited by possible damage to the perineal muscles and nerves in the incision, by pressure of the tube, or by late scarring in and around the wound.

(ii) *Suprapubic drainage* has three advantages over other methods. The absence of any foreign body in the urethra eliminates genital infection; urine can be collected by means of various types of apparatus while the patient is ambulant, and thirdly, such drainage can be maintained indefinitely.

Unfortunately the defects of suprapubic drainage are only too apparent, the most obvious being leakage of urine around the tube with its attendant discomforts both physical and mental. When the cystostomy opening is low enough to become adherent to the symphysis pubis, urinary leakage becomes more or less continuous throughout the 24 hours. Riches (1943) advises an opening placed midway between the symphysis pubis and the umbilicus and his simple and ingenious method of suprapubic catheterization is most effective in preventing leakage. Blind suprapubic puncture, however, at this level may damage the peritoneum when the reflection of this membrane in front of the bladder is low and this is more likely to occur in fat patients when the fundus of the distended viscus is not readily palpable. Accidents of this kind are common enough to impose a severe handicap on these methods and the only certain

means of avoiding them seems to be by deliberate exposure of the bladder wall through a small incision before the puncture is made although, of course, this will increase the tendency to leakage.

Because of the limited relief afforded by suprapubic cystostomy many surgeons regard this procedure as a confession of failure in the treatment of the enlarged prostate and avoid it at all costs. This attitude is shared by our patients who, however elderly and feeble and however remote they know their chances of survival to be, will rarely refuse prostatectomy as a means of ending their sufferings one way or the other.

A less obvious but far more serious defect of suprapubic cystostomy is that of uphill drainage. Any feeble siphonage by the tube is subject to frequent interruptions by kinks, air-locks and other forms of blockage. The bladder is never completely emptied and, even under the most favourable circumstances, always contains an ounce or more of residual urine. We are reminded of this fact by the gush of urine that follows the withdrawal of a suprapubic tube, also by the immediate appearance of urine whenever a urethral catheter is passed. A further illustration of the incompleteness of suprapubic drainage is the possible formation of vesical calculi and although this is more prevalent in paralysed bladders the author has, on several occasions, removed large calculi after cystostomy in patients suffering from prostatic obstruction.

The mortality rate of suprapubic cystostomy in cases where radical surgery is contraindicated has been stated by various writers to vary from 10 to 30 per cent. Rees (1947), for instance, reported 30 deaths amongst 106 patients so treated at Queen Elizabeth Hospital, Birmingham (mortality rate, 28 per cent.). In this series of cases post mortem examinations revealed the cause of death to be some form of urinary infection, chiefly pyelonephritis, in more than 50 per cent. While it must be conceded that a considerable proportion of cases of this type are suffering from advanced cardiovascular and other non-urinary diseases and are beyond medical aid, it is equally obvious that the high incidence of fatal urinary infections might well be due to the method used to drain the obstructed bladder. In other words, the mechanical defects of uphill drainage together with contamination of residual urine in the bladder is likely to give rise to ascending infection in an upper urinary tract already damaged by the effects of prolonged obstruction.

For purposes of comparison 58 'poor risk' cases with chronic retention whose blood ureas on admission to hospital ranged from 40 to 290 mgm. per cent., were drained by urethrostomy. There were five deaths in the series, four due to cardio-

vascular causes (two cardiac failure, one pulmonary embolus, one coronary embolus) and one to renal failure due to gross dilatation of both kidneys and ureters following bladder-neck obstruction of long standing. The complete elimination of fatal urinary infections in this series of cases by the substitution of dependent for uphill drainage requires no further comment.

(iii) *Catheter drainage*, though simple and convenient has one important limiting factor to its usefulness, namely, urethritis. The retained catheter will act as a foreign body in the urethra, first stimulating the activity of the mucus-secreting glands, which are most abundant in the mid-portion of the anterior urethra, and, after two to three days giving rise to an inflammatory reaction, the thin mucoid secretion becoming frankly purulent. The infection is primarily caused by the staph. albus and aureus with coliform and other organisms (s. fecalis, b. proteus, b. pyocyaneus, etc.) appearing later as secondary invaders.

Various mechanical factors may aggravate the effects of this local inflammation. Firstly, a catheter tightly fitting at the external meatus will prevent drainage of urethral secretions beside it so that pus will tend to accumulate in the anterior urethra under tension. This is often made still worse by the presence of tapes, strapping or other retentive apparatus. The size of the catheter in relation to the external meatus is the most important factor in determining the severity of the reaction in the urethra. When the urethra is large there will be no interference with free drainage and the reaction will be mild; when small, however, pus under tension may be forced backwards to the bladder or along the ejaculatory and prostatic ducts. Blockage of the mouths of Littre's glands in the more severe degrees of urethritis may lead to periurethral suppuration and when this involves the peno-scrotal region a permanent stricture or fistula may result. A tightly fitting catheter may sometimes give rise to actual pressure necrosis at the meatus and subsequent ulceration in the fossa navicularis will lead to a dense stricture at the urethral outlet. A severe 'catheter' stricture of the meatus is a serious and permanent disability and the patient who finds, on leaving hospital after prostatectomy, that he has merely exchanged one form of obstruction for another may feel that he has made a bad bargain.

The external meatus, the narrowest and least distensible part of the male urethra, is subject to wide variations in size in different individuals. In order to gain some exact information as to the range in calibre of this part of the normal urethra, notes were made of 100 consecutive cases at operation

where there was no history of previous catheterization or of urethral disease. Using a 22 Charriere rubber catheter as a 'standard' it was found that 47 urethrae were 'normal' (i.e. the instrument passed easily), 23 were classed as 'tight' (i.e. the instrument could be passed only after dilatation) and 22 were 'very tight' (calibration 20 Ch. or lower). Only eight of the series were classified as 'large' (i.e. 24 Ch. or over) and considered suitable for urethral catheter drainage for periods of seven days or longer.

Oedema of the external meatus may be an important additional factor in preventing drainage around a tied-in catheter and tends to vary inversely with the size of the opening. In some cases oedema may cause a loosely-fitting catheter to be tightly gripped in 24 hours, thus rendering a normal-sized urethra quite unsuitable for further catheter drainage.

Other factors influencing urethritis, such as the time factor, rigidity of the instrument, amount of movement, prevention of contamination of the outside of the catheter, etc., can be more readily controlled.

(iv) *Urethrostomy* drainage of the bladder has been carried out for many years at St. Peter's Hospital in the treatment of urethral stricture. Harrison (1878) recommended the introduction of a tube along the posterior urethra to drain the bladder after external urethrotomy or perineal section as a means of preventing post-operative febrile reactions. It was not until 1885, however, that he described the operation of combined internal and external urethrotomy with urethrostomy drainage with which his name is now associated. Originally recommended for 'impassable or very extensive strictures which will not dilate,' the operation was also used in 'cases of periurethral abscess, fistula or extravasation' and eventually came to be employed exclusively in the latter group. The value of combined perineal drainage of both the bladder and the subcutaneous tissues in cases of stricture complicated by gangrenous cellulitis ('perineal phlegmon'), was emphasized by both Freyer and Thomson-Walker and is still to be regarded as the method of choice in these cases, for, in addition to providing a direct escape for urine from the bladder by the most dependent route it avoids opening up fresh planes of tissue. Most of us have looked on helplessly whilst a spreading gangrenous cellulitis of the abdominal wall or a gas infection has developed after suprapubic cystostomy in cases of this kind, yet how easily this could have been prevented by drainage from below. Fortunately the so-called perineal phlegmon is becoming less common nowadays but in the half dozen cases the author has treated by combined perineal section and urethrostomy in

the past few years it has been gratifying to watch the rapid recovery of patients who exhibited all the signs of the profound toxæmia so characteristic of this form of urinary suppuration when admitted to hospital. Furthermore, the infection both in the urinary tract and the cellular tissues has cleared up rapidly and completely. Incidentally the divided stricture has become more amenable to dilatation afterwards.

Apart from its occasional use in urethral stricture, urethrostomy drainage of the bladder has never been popular with urologists in this country although it appears to have been extensively used for some time in the United States. Young and his associates (1926) recommend this procedure for diverting the urine when operating for hypospadias and other deformities of the penis, and the majority of British plastic surgeons now follow this example. Young (1934), discussing the treatment of the obstructed bladder, advised the substitution of the urethral catheter for suprapubic drainage because of the high mortality of the latter. Where the urethra did not tolerate a catheter well he advised urethrostomy drainage. Barney (1934) described the simple method of performing urethrostomy with catheter and clamp used by him for many years. Lewis (1943) advocated urethrostomy for drainage of the paralysed bladder and claimed that there was less leakage, less infection, better drainage and, in fact, many advantages over other methods.

Dissatisfaction with routine methods of bladder drainage by cystostomy or urethral catheter led the author to explore the possibilities of urethrostomy for this purpose early in 1946 and during the past two years it has been employed almost exclusively in more than 300 cases.

The following table shows the various conditions treated by urethrostomy drainage :—

	Cases
Temporary or pre-operative bladder drainage ..	58
Post-operative drainage :	
a. Prostatectomy, one stage (retropubic, Freyer, vesico-capsular) ..	157
b. Prostatectomy, after suprapubic drainage ..	55
c. Prostatectomy, after urethrostomy drainage ..	49
d. Perurethral resection ..	8
e. Diverticulectomy ..	24
f. Operations for carcinoma of the bladder (open diathermy, partial cystectomy) ..	16
g. Miscellaneous (excision of stricture, perineal phlegmon, calculus, etc.) ..	12
Totál ..	379

The method used in the majority of the cases was that described by Barney and will be subsequently referred to as the 'closed' method. A rubber catheter is passed along the urethra to its

full length and the distal end securely clamped with a curved artery forceps (Moynihan or curved Spencer Wells pattern). The forceps is advanced until its beak reaches the bulbous urethra and by rotating the handle through 180° the point is made to present in the perineum where it is cut down upon. The end of the catheter is disengaged from the forceps and is withdrawn through the incision to the correct length for bladder drainage. This method is rapid, simple and requires no special equipment. In seriously ill patients it can readily be performed in bed under local anaesthesia. In that group of cases, comprising about 20 per cent., where the external meatus is stenosed or the urethra congenitally small, the 'open' method has been employed. An incision is made in the perineum on the curve of a small metal bougie dividing the skin, fascia, bulbocavernosus muscle, the spongy tissue and the urethral mucosa. The edges of the latter must be carefully identified and grasped with fine tissue forceps before attempting to pass the catheter, otherwise the urethra will tend to invaginate and prevent the passage of the instrument. The open method is much more difficult than the closed method of urethrostomy as it requires wider dissection in an extremely vascular area. It should not be attempted under local anaesthesia.

The best position for the urethrostomy opening has been found to be in the scrotal raphe about one inch in front of the perineo-scrotal angle. The site of this opening is a matter of some importance. If placed too far back it is less accessible for nursing, contamination from the anus is more likely, kinking of the tube by the weight of the scrotal contents is hard to avoid and spontaneous closure of the fistula after removal of the catheter is slower. If too far forward the catheter tends to kink excessively at the subpubic angle and if it should come out replacement may be difficult.

Transfixion of the catheter was found to be unsatisfactory mainly because of leakage from the stitch hole in the rubber and the best method of fixation so far devised has been by numerous half hitches around the catheter stitched to the skin in front. Silk, nylon or other non-absorbable sutures serve equally well.

For post-operative drainage after prostatectomy, partial cystectomy, etc., a 'whistle tip' resectoscope catheter with at least three lateral eyes has been found to be the most satisfactory. The perineal urethra will readily accommodate 22 and 24 Ch. sizes and when haemorrhage was not well controlled size 26 Ch. has been used on several occasions. In three cases urethrostomy has been combined with suprapubic drainage and drip-irrigation when severe haemorrhage had occurred after Freyer prostatectomy; as an alternative to

the latter method a Foley type of catheter was introduced by open urethrostomy on one occasion and control of bleeding was complete.

The best position for nursing the patient seems to be with the tube draining over the thigh and the scrotum supported by means of an elastoplast bridge.

Disadvantages of the method are as follows:— Firstly, a scrotal haematoma may form. This does not appear to be a matter for great concern as rapid absorption without infection has been the rule in the cases observed. Secondly, replacement of the urethrostomy tube may be difficult, especially if the attempt is delayed for more than a few hours. An opening made too far forward will further increase the difficulties of replacement. Thirdly, slight incontinence of urine is not uncommon, especially after prolonged drainage with the larger sizes of catheters. This is not severe and full control normally returns within a few weeks. No case of permanent incontinence has been observed. Finally, leakage of urine from the resulting perineal fistula after removal of the tube will occur with each act of micturition. This is, of course, normally under voluntary control. It ceases, in the average case, after four or five days, but may persist longer if the opening has been made too far back in the perineum or if circumstances have made it impossible to get the patient out of bed immediately after removal of the tube. In one of the cases after prostatectomy severe haematemesis from a duodenal ulcer necessitated three months' treatment in bed. On getting the patient up at the end of this time the perineal fistula, which had leaked intermittently all this time, closed spontaneously within a few days. In the erect posture the weight of the scrotal contents tends to drag the external opening away from the urethra and thus accelerates the obliteration of the track. In all these cases, healing was spontaneous. Leakage is undoubtedly the chief disadvantage of urethrostomy drainage but it is, after all, a small price to pay for the added safety the method confers on 'closed' operations on the bladder. Unlike the leakage associated with suprapubic cystostomy it is, however, under voluntary control. It is always necessary to warn patients of leakage before removing a perineal tube and to reassure them that this will only be a temporary state of affairs, otherwise they are apt to assume that some mishap has befallen them.

Most of the advantages of urethrostomy, especially the simplicity of the procedure, have already been emphasized. Compared with suprapubic cystostomy the outstanding features are the difference between dependent and uphill drainage and, in bladder obstructions, the striking contrast between the mortality rates of the two methods.

Other features favouring urethrostomy are; first, an intact abdominal wall after pre-operative drainage instead of an infected abdominal tube track, so that a subsequent suprapubic operation is safer, easier and cleaner; secondly, post-operative drainage of the bladder is away from the suture line and allows complete closure in most instances. Compared with catheter drainage the main advantage is the avoidance of most of the ill effects of urethritis by excluding nearly two-thirds of the entire urethra; furthermore, there is always adequate provision for free drainage alongside the perineal catheter. In addition, the larger sizes of catheters, better methods of fixation, elimination of the distal (pre-pubic) bend of the urethra, the abolition of any time limit, are all factors which make urethrostomy preferable to catheter drainage with the possible exception of that small group of cases where the external meatus is large and where drainage will probably not be required for longer than seven to ten days. While it can be said that a stricture will almost invariably follow incision of the penile urethra it can be stated, equally dogmatically, that this complication is unlikely to occur in the perineal urethra unless the entire circumference has been divided and the ends separated.

Summary and Conclusions

1. Suprapubic cystostomy offers no real solution to the relief of bladder obstructions because, in the first place, it is mechanically unsound and will always be associated with a high incidence of urinary infection; secondly, permanent suprapubic drainage is worse than a sentence of death to most individuals and almost any operative risk is justified in avoiding it. In the treatment of the paralysed bladder, however, suprapubic drainage appears to be still the safest and most satisfactory method for routine use.

2. Having regard to the severe effects of traumatic urethritis, both immediate and late, the indiscriminate use of the tied-in catheter to drain the bladder for periods exceeding two or three days is condemned. Less than 10 per cent. of the urethrae examined were found to tolerate a catheter of size 22 Ch. or larger, for longer than a week and only this small group can be considered as suitable for this form of drainage.

3. Urethrostomy drainage, though not ideal by any means, goes a long way towards solving many of the defects of the other methods. When bladder drainage is required pre-operatively, urethrostomy has the great advantages of mechanical efficiency, simplicity and added safety over other methods. As an alternative to immediate prostatectomy, particularly in the 'poor risk' case with extra-urinary complications,

urethrostomy will, it is held, be found to yield the best results. Post-operatively it confers an increased margin of safety on complete closure after operations on the bladder or prostate. Furthermore drainage can be maintained indefinitely in order to ensure sound healing of the abdominal wound.

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THE ISCHAEMIC LIMB

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The proper nutrition of a limb depends on, amongst other things, a sufficient blood supply. The main arteries to a limb may become obstructed to a remarkable degree, in fact, they may be completely obstructed without the patient's knowledge, and often without his medical attendant's knowledge, because alternative pathways exist. Apart from sufficient patency of the vessels, an adequate cardiac output is necessary, which depends on sufficient cardiac return and consequently a proper blood volume. Thus in severe arterial trauma causing an interruption of a main vessel, the life of the limb may become precarious, not only as a result of damaged vessels but also of a diminished blood volume resulting from severe haemorrhage at the time of the incident, and a timely and possibly massive blood transfusion may well tilt the scale towards recovery of the limb. Thus the factor of anaemia must be considered as well as the patency of the vessels.

Ischaemia of a limb may occur in the following conditions :

- (1) *Trauma*, causing rupture, contusion and thrombosis, spasm or later aneurysm of an artery.
- (2) *Embolism*, from a fibrillating auricle or valvular vegetation, from atheromatous plaques in the largest vessels, and in paradoxical embolism, where there is patency between the right and left side of the heart, from the venous system.
- (3) *Thrombosis*, where the vessel wall is diseased as in arterio-sclerosis, thromboangiitis obliterans

or syphilis, or when the vessel is compressed, as in cervical rib, or invaded or compressed by tumour, or in severe blood diseases and infective conditions such as typhoid or pneumonia, the seat of intraluminal clot.

(4) The so-called *spontaneous monarteritis of indeterminate origin* (Learmonth), in which there is no overt cause of thrombosis.

(5) Certain *spasmodic conditions* such as occur in the Raynaud syndrome, traumatic arterial spasm and, it may be, as a reflex phenomenon in certain cases of venous thrombosis, though this must be rare.

Apart from trauma and spasm it will be seen that arterial obstruction results from embolism or thrombosis, and even in these two conditions thrombosis is generally the factor which finally seals the fate of the limb.

Morbid Anatomy

Whether the original obstruction be due to thrombosis or embolism the important factor is the rapid addition of clot with blockage of valuable collateral vessels, further embarrassing the circulation. A clot may extend widely, even through the whole length of a limb, and from the distal end of this clot fragments may break off and block more distal vessels previously unaffected. This is not infrequently seen when a rib presses on the subclavian artery (resulting in dilatation beyond the point of pressure, together with the formation