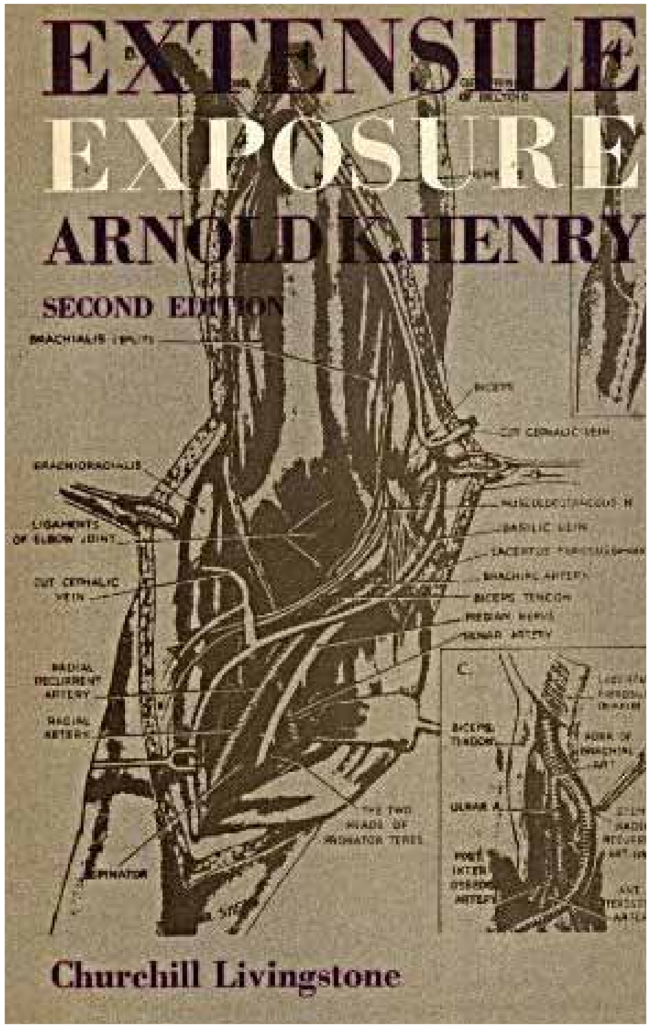
Extensile Exposure

[2nd Edition]



Arnold K. Henry

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EXTENSILE EXPOSURE

by

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"'tis not so deep as a well, nor so wide as a church door;
but . . . 'twill serve."

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TO MY WIFE

PREFACE TO SECOND EDITION

IF, as one keeps on hearing, the sort of anatomy untastefully called 'gross' were really finished, this re-edition would count only as a further impertinence. But while its predecessor was received with unexpected kindliness, the not-intolerant climate held just the echo of a salutary feline note : "It's all very interesting," said the Miller's Cat to the Mill-race, "but if you could manage to do your work—whose value I don't in the least dispute—a little more soberly, I for one should be grateful." Meanwhile, however, Time, which finds ways of settling sobriety's worse disorders, has not been idle.

The former edition was written firstly for my friends, and it is by the wish of some of them that I include (or, if you will, thrust in) old and more recent work for convenient access. And since several of these adjuncts go beyond the scope of limbs, the re-edition's title, though still 'Extensile,' is shorter by a tail. Otherwise I have left the text much as it was so that parts of it will 'date'—perhaps respectably like things men excavate which keep about them "glories of their fallen day"; for instance, bipp—in Richard Stoney's hands. But bipp, some find, has strong survival value; and lately, like the coelacanth, it has turned up again.

The present progress in surgery is so rapid that one year now is like a former hundred, and ten can leave us not outstripped but at the post. Even simple straight incisions have been altered, and I am most grateful for the chance of taking my impressions of their modern trends from a variety of patients, with scars long-healed and admirable, put at my disposal by the courtesy of Mr J. C. Sugars of the Adelaide Hospital, Dublin.

Approaching recent art one has at times to wrench oneself towards acceptance. Yet, after all, I should not grumble ; these new cuts suit my thesis : their turnings keep incisions long.

Let me revert to the gross anatomy which I have tried to teach for almost ten years in the uniquely happy circumstance of this old College. Some while back a distinguished exponent of my subject told me that his first answer to new students asking what they should read was, " A dictionary." That sound advice gains, I find, with experience. " Light dies before the uncreating word."

Our own terms are Greek or Latin—' Greek ' sometimes to ourselves. Yet when an Oriental candidate writes " the pulmonary of the sacrum " or " aleolar tis," we suffer shock. How fortunate for us that Sanscrit or Arabic did not preponderate directly in forming current medical nomenclature !

For good or ill there will always be division between the arts and the bleakness of science. It need not be absolute : like earth and sky they are apart but they communicate at times by flashes. A rare example must serve in lieu of portrait of a friend and colleague whose name and work recurs through the text. Once, after a class on the larynx at which I had to confess that I did not know the meaning of the word ' arytenoid,' I met T. P. Garry on my way out and enquired. " Arytenoid . . . ? " he said ; " shaped like a vase : Ruth at the well with her pitcher balanced uneasily on her shoulder like the arytenoid on the shoulder of the cricoid."

The reader who would wish to match that satisfying gleam with competence in practice may note—if he have patience to arrive so far—the explanation of how a finger working blindly deep in the pelvis can with quasi-certainty (the only sort anatomy will grant) find and pick up a hip-joint twig and part it from the main sciatic stem. Yet the talk is that gross anatomy has died. One might imagine it instead decrassified and taking wing.

In a former preface I tried to specify my gratitude to those who helped me with the first edition. Some of them through the past ten years have never ceased in helping me to re-edit—Miss Zita Stead, my artist ; Mr Charles Macmillan, Managing Director of Messrs E. & S. Livingstone, my publishers ; more recently my indispensable secretary, Miss D. MacDaniel. Repeated

thanks are apt to seem like hollow resonance, so I will only say that patience—tried as theirs—is rare indeed.

My friend, Col. G. M. Irvine, till recently my colleague, has warded off, and even assumed, many distracting burdens on my behalf.

I have attempted to acknowledge other debts in relevant parts of the text: to my former Surgical Demonstrator, Mr W. A. L. Macgowan, and to Mr M. Stranc. Thanks are due in a special degree to my present Lecturer, Dr M. Levine, and to Dr O. Singer for their sketches; also to my Demonstrator, Mr M. S. Matharu, for his clear photography.

Not least am I grateful for the loyal collaboration of my technical staff in and out of the Dissecting Room: Robert Syms, William White, and that wise and kindly person Harry McCabe, who died recently and whom I knew during most of the forty years of his honourable service to these famous Dublin "Schools of Surgery," thus curiously named since 1789, but in fact the modern school of medicine of this Royal College and a lively source of world-wide education. It is a School unique, I think, in several respects, notably perhaps for quiet friendliness, of which I know its students carry much that matters to their patients.

ARNOLD K. HENRY.

THE ROYAL COLLEGE OF SURGEONS,
DUBLIN.
May, 1957.

PREFACE TO FIRST EDITION

EXPOSURE that will vie effectively with the "great arsenal of chance" must be a match for every shift, and therefore have a range, *extensile*, like the tongue of the chameleon, to reach where it requires. This book, accordingly, seeks to enlarge the scope of certain set and parcelled methods of approach. It deals with means in which my confidence has grown from using them myself and watching others try them. And while a smooth success with first attempts pleased all concerned, mistakes (made as they were by persons of intelligence) proved real auxiliaries: they marked exactly what was ill-conceived or insufficiently described, and gave the chance for second thoughts—a chance these pages strive to seize.

Bone carries our anatomy and forms its central fact, and bone wherever possible is made the core of each exposure. Even the few confined to nerves and vessels bring in a glimpse of skeleton; and some of these (though well rehearsed in other books and easily accessible) are borrowed here again. They form the roots from which exposures spread, and serve—like roots—to bind irrelative surroundings. The presence, too, of things so instantly attractive has let me note where charm may breed a moth-and-lamp effect that makes us "strut to our confusion."

The page who sings in *As You Like It* is correct: "hawking, or spitting, or saying we are hoarse" are only prologues to a bad voice; and books, like songs, should be their own interpreters. But it is rare that one unaided person can write, print, illustrate and publish them. So debts alone may justify a preface; and mine are large. My secretary, Mrs A. Wenham Brown—as quietly concerned for "a mistake in the dust of a butterfly's wing as in the disk of the sun"—has given deft, invaluable help at every stage, and latterly with indexing. Miss Zita Stead, the artist, adds to her gift the knowledge gained from actual dissection—a rare concurrence, used by her with scrupulous regard. Then, too, I have been fortunate to meet with a collaborator at once so expert, sterling and considerate as Mr Charles Macmillan, of Messrs E. & S. Livingstone Ltd., my publishers; he puts a Scottish heart into his work.

To Professor J. H. Dible and the staff of his department I venture to express my gratitude for opportunities of contact with a welcome, stimulating climate—the evidence and birthright of a university. Dr J. Pritchard, too, at the Department of Anatomy, St. Mary's Hospital, has given me much friendly help.

That excellent technician, Mr J. Robson (now in the R.A.F.), has earned my special thanks, together with his friend, Mr V. Willmott, a very skilled photographer: their cheerful courtesy, and that of Section Commander C. Ward, was aid indeed.

The text in a superlative degree owes weeding and correction to my wife.

Lastly, a debt is due throughout to surgeons from every quarter of the Commonwealth. In friendly groups they formed (unwittingly) a panel whose jurors brought me verdicts; and so these pages print what seemed to win, if not their full, unqualified approval, at least an *imprimatur*. Should I be wrong in that belief, the process of acquiring illusion for once sits smiling to the memory.

ARNOLD K. HENRY.

July, 1945.

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SECTION IV

THE LOWER LIMB

INTRODUCTION

NOMENCLATURE

. . . *d'abord la clarté, puis encore la clarté et enfin la clarté.*
—ANATOLE FRANCE.

Throughout the world in general—and, notably, in that of those who think and write—I find it only in the ratio of the diamond to the mass of the planet.
—PAUL VALÉRY.

A NEW nomenclature has recently appeared amongst anatomists—the third in thirty years; and so, for men of different age, a class to-day in operative surgery is something like a class in Babel: one does not speak to it collectively.[1]

I hold no brief for any terminology; the new, the old, the Basle have each their points. The new, for instance, turns from the vague "axillary" nerve of Basle back to the old and graphic circumflex. But change which darkens what was clear is less commendable. The trunk, for instance, that we knew (and still know well) as musculospiral, ended by forking into branches named respectively the "radial" and "posterior interosseous." This trunk then fell in line with continental usage and became the radial of Basle nomenclature; its terminal divisions, too, were well described as "deep" and "superficial." The third and new nomenclature confounds the trunk and superficial branch, and *both* are now called "radial." With that peculiar precedent of lost distinction the internal popliteal nerve (*alias* the tibial, *alias* the medial popliteal) might easily—in mounds of new editions—be called "sciatic."

An opportunity is ripening; like us, America and the Dominions have now had time to sift the question of nomenclature in English. Is it too much to hope that any joint, definitive agreement will bear convincing signatures which prove

[1] This flux is not peculiar to anatomy. Dons have it too; Hilaire Belloc records the fact: "They have turned the pronunciation of Latin (whereof we might have made a common tongue for general intercourse) quite upside down, consonants and vowels and diphthongs, so that my contemporaries can remember at least three quite different ways of pronouncing the simplest Latin phrase, three different fashions in the short space of a human life. Perhaps a fourth is coming." For Dons, he adds, are capable of anything.

it acceptable to those who work in *live* anatomy? Till then let criticisms rain, but may there be a truce to efforts at establishing parochial adjustments!

And meanwhile with Herodotus, who cared for clarity and was (like us) unsettled by kaleidoscopic terms, "I shall continue to employ the names which custom sanctions,"—names which I know our surgeons understand. So without fear of puzzling anyone I say "the upper end" of humerus, or, if I wish, its "proximal extremity." Nor shall I waive the right to use "inner" and "outer"; "internal to," "external to"; "inwards" or "outwards." "Medial" and "lateral" are useful words; I shall employ them too, but not *ad nauseam*; the English tongue resents a curb, and answers best when reined discreetly. Perhaps for reasons similar the French (who then had much to lose) refused to bow the knee to 'Basle.'

We recognise[1] at once the inner aspect of the thigh (or arm or leg), so why not speak of it? And though the present fiat of anatomists restricts the term of "inner surface" to linings of the hollow organs, yet, if I write that certain nerves lie to the inner side of arteries, will someone really think they lie within the lumen?

Such things, of course, are trifles weighed against the fact that every terminology has pockets of resistance to surgical approach. And these (within the boundary of my text) I am resolved to liquidate.

ON CERTAIN AIDS DERIVED FROM STRUCTURAL ARRANGEMENT

The operations of our intellect tend to geometry.
—HENRI BERGSON.

Que ferions nous sans le secours de ce qui n'existe pas? . . . Les mythes sont les âmes de nos actions.—PAUL VALÉRY.

Some general considerations.—Few that invade the structure of anatomy are artists; the great majority take care, for the convenience of their memories, to force its details into shapes of Euclid—triangles, quadrilaterals, circles of peculiar form. The few (and they are very few) need no such framework; like painters who from scribbled notes of "green" or "yellow" produce a replica with tone and shade in exquisite gradation,

[1] *Recognise, recognize*; *mobilise, mobilize*, etc. The *Oxford English Dictionary* is strong for "z." But Pater who was 'Oxford' allows the "s"—like Quiller-Couch of Oxford *and* of Cambridge. I shall abide by *Kent's* uncompromising verdict (*King Lear*, Act II, Sc. 2).

these few as easily recall the un-Euclidean visage of anatomy and deal with it as though by instinct.

The many (like myself) who fail to share the artist's gift are glad of aids—despised by those who do not need them. And here the targets for their scorn are plentiful: these pages nowhere scruple to include whatever crutch or simile or dodge has proved its worth repeatedly to groups or individuals. I am, indeed, convinced (like Tristram Shandy's father) that there exists "a North-west passage to the intellectual world, and that the soul of man has shorter ways of going to work, in furnishing itself with knowledge and instruction." Things, therefore, such as satellites, loop-holes, half-sleeves, shoulder-straps, cloaks, seams, leashes, bucket-handles, lids, sandwiches, V's, and manual mnemonics—these myths are rife throughout. Let us examine one or two more closely.

The half-sleeve.—By this I do not mean a sleeve cut short across but one divided lengthwise, covering subjacent structures somewhat in the way a cradle covers patients suffering from shock. We come upon such half-sleeve muscular investments behind the shaft of humerus; in front of the femur; at the back of the calf. In each half-sleeve there is a seam to find and rip —giving the latter word precise, housewifely meaning, remote from crime or even butchery.

Loop-holes.—A muscle in the space between attachments must have a portion of its belly 'free,' that is to say continuous with everything surrounding it in such a way as to allow of normal action and harmless instrumental separation. These parts when short and when we separate them out will form the boundary of a loop-hole which may give initial access to a deep and perilous position. A useful fingerbreadth of biceps, for example, close to the distal end of femur, lies free behind the intermuscular septum; a touch will make the belly bound a loop-hole which can then be widened safely.

Satellites.—This term of satellite denotes a state of linked companionship, like that of median nerve with the sublimis belly, or of its ulnar neighbour with profundus; for, coming from behind into the forearm, the latter trunk is fastened to the deeper muscle. A satellite relation thus implies reciprocal divorce from other structures. Specific application of this knowledge— of union as distinct from mere proximity—prevents much futile groping (pp. 100 and 221).

Other aids.—We should contrive to wring the utmost benefit from details of anatomy; examples of this kind of exploitation are scattered through the text. Contributors in this respect are planes of cleavage, and I try to show how best to find them. Other aids abound. A bursa, for example, may help to make our surgical approach as smooth and easy as the gliding of its own

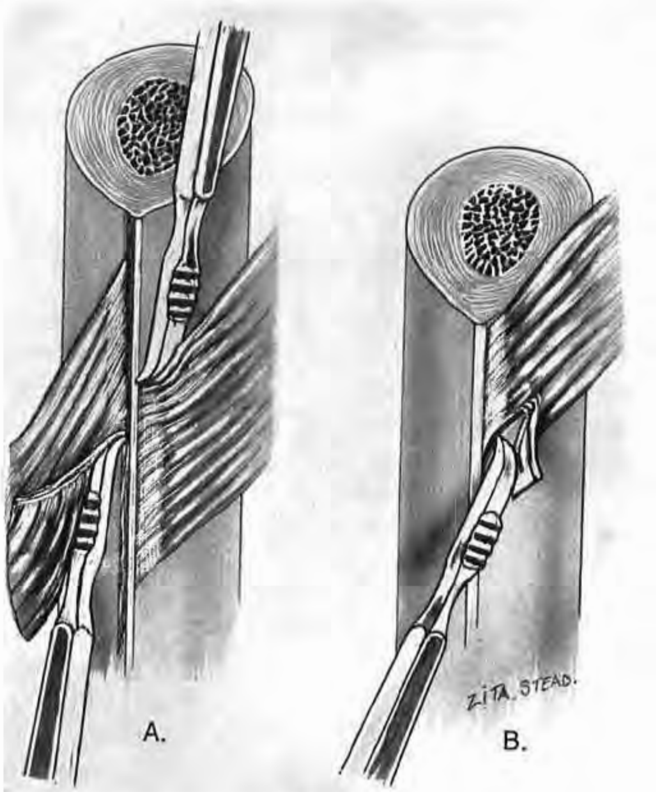

Fig. 1

The stripping angle

Work the rugine into the acute angle which fibres of muscle or interosseous membrane make with bone. (B shows how the rugine tears into a muscle when used in the reverse direction —against the obtuse angle.)

tendon (p. 101). Or fibres from another source may cross and bind the grain, say of the popliteus—a muscle that when split gives only meagre access. The crossing fibres then will mark a line for sectioning the muscle and also stop the creep of sutures through the grain (p. 261). A structure tethered on a single border will move more readily towards its tether, uncovering objectives deep to it; so, to reach them easily, divide the skin along the border *opposite* the tether (p. 268). Angles of attachment help or impede the separation of fibres from bone. And muscles grasped and moved across their fixed companions provide the surgeon with a kind of tangible mnemonic which helps him for incising skin and separating structures (*The Lancet*, 1940, **1**, 125). Allusion to these angles and mobilities are frequent in the text and need some further explanation.

Fig. 2

Comparative muscle mobility

The biceps—fixed at either end—can easily be moved across the widely fastened breadth of brachialis. Thus, for exposure of the front of the humerus, the *fingers* can discover (in spite of fat or swelling) exactly where we should incise and where to find the part of brachialis that separates shaft from skin.

The acute or stripping angle.—A shaft is stripped most easily of fibres, whether of muscle or of interosseous membrane, by working the edge of the rugine into the *acute* angle which the fibres make with bone at their attachment.[1] Used in the opposite direction—towards the obtuse angle—the rugine tends to leave the bone and tear into muscle or membrane (Fig. 1). There is a two-way application of this principle when we expose the shaft of femur ; here the stripping angle opens proximally for adductors, distally for vasti. Then, too, on the fibula the muscles have a stripping angle opposite to that of interosseous membrane (pp. 294 and 296).

Comparative muscle mobility.[2]—We can make use before and during operation of the facility of moving certain muscles across their much more fixed companions. Lines of incision may

[1] Rooks, as members of the crow family, rank with " the most intelligent of birds." *They* use the stripping angle when they pluck twigs for nesting, but with a difference : standing below the upward slant they tug from the obtuse angle. (M. Burton, D.Sc., *Illustrated London News*, October 8, 1955.)

[2] *The Lancet*, 1940, **1**, 125.

thus be ascertained where fat, posture or swelling might cause disorientation; and planes of cleavage, too, can be located by this means. Before we cut down on the front of the humeral shaft we first shall grasp and move the free biceps belly across the widely fixed attachment of brachialis fibres, and thus find out exactly where to split the portion of this latter muscle which separates the skin from bone (Fig. 2). Behind the humerus we move the long free head of triceps in relation to the lateral fixed head, and so find out exactly where to split the loose half-sleeve with which this pair of superficial elements covers the musculo-spiral nerve and deeper head (p. 18). A wad of three long bellies flanks the radius and must be mobilised before we clear its shaft. The fingers move these muscles to and fro *en masse* across the supinator and against the fixed extensor bellies. So we can feel out lines for skin incision and planes of cleavage, front and back: in front, when we approach the shaft of radius (p. 102); behind, in looking for the posterior interosseous nerve—the deep (terminal) branch of radial in Basle nomenclature (p. 115). The stiff edge, too, of lateral intermuscular septum (a structure vital to one femoral exposure) is recognised by moving the lax mass of biceps across its greater fixity (p. 219). Lastly, for access to ulnar bursa, mid-palmar space or deep terminal branch of ulnar nerve, finger and thumb locate and move abductor digiti quinti in the free margin of the hypothenar mass.

Separation of closely related structures.—We shall in general contrive to separate these structures cleanly if we begin their separation at the place where they begin to separate—a precept which Fiolle and Delmas stress throughout a book that is the breath of present-day exposure.[1] This principle has widespread application: it works, I find, as smoothly in the chest as in the limbs. The flimsy sacs of pleura tear unless we start divorcing them where they divorce themselves to clothe the apex of the lungs (p. 143). So on the limbs we look for places of divergence: a member of a bundle turns aside, or crowded bellies fan towards their tendons.

Sometimes, as we shall see, a pair of thumbs (well gloved, of course) laid lengthwise on a pair of bellies will open up a twisting plane of separation—technique that will be blamed by those who have not learnt to trust the hand, the quintessential root—in every sense—of surgery.

[1] J. Fiolle and J. Delmas, *Surgical Exposure of the Deep-seated Blood Vessels*, London, 1921.

THE CUTTING OF CUTANEOUS NERVES

So when the buckled girder
Lets down the grinding span,
The blame for loss, or murder,
Is laid upon the man.
Not on the Stuff—the Man!

—RUDYARD KIPLING.

Incisions must divide the *branches* of cutaneous nerves, but they should aim to cut as few as possible and should at least avoid the major stems. Once in a while painful neuroma follows their section or their injury, giving the patient little rest and sometimes ruining a life. These cases, though infrequent, are living accusations. We should endeavour not to swell their ranks.

Incisions will be planned accordingly. I have twice lately met with scars of operation on the knee, U-shaped and classical, giving rise to sharp and frequent pain, in one case lasting seven years—an extra reason for discarding crooked cuts. We can as easily excise the knee—or do whatever else we must—through an incision that is straight and *shorter* than the U. (A piece of string bent and unbent will illustrate the point.) Apart from nerves, however, the U that cuts the blood supply on either side of skin tends to produce a marginal necrosis.

In certain regions it will not be possible to heed these atraumatic counsels: a large exposure in the neck or shoulder *must* cut some large cutaneous nerves, rarely indeed with after-penalties, though I have seen two patients recently whose broken clavicles had injured branches from the neck, causing neuralgic pain. And often, in the fingers, trigger-spots arise from tiny twigs in necessary scars.

These then are counsels of perfection. Yet, if we look, we recognise abundant opportunities of sparing nerves, which those in daily contact with post-operative limbs will try to seize. Some, too, may find (as I believe) that these cutaneous disasters, though commoner in people with a certain temperament, can yet assail the balanced individual. To *all* of these unfortunates the pain is real, and little satisfaction can be got by blaming them for faults of therapy or chance.

Such lesions should be treated urgently before the pain takes root within the thalamus, thence to wear slowly out; or else wear out the patient. For when the thalamus is sick no surgery can cure—except the guillotine.

Sometimes in early cases we succeed immediately. A procaine infiltration of the trigger-spot, if followed up at once by movement, may stop the pain; and even (rarely) after long duration. (This happened with the painful knee I mentioned, which was cured for months by two injections—till the patient fell and bruised the scar.) But failure, too, is common. Sometimes resection works a charm (it cured my two clavicular neuralgics) —or sympathectomy. They often fail. There is no rule whatever. Therefore (once more!) let us respect cutaneous nerves.

TECHNIQUE

I shall guard my asepsis as a girl should guard her virginity.
—A colleague, thirty years ago.

This modest note may find a welcome now that bones and joints will come the way of general surgeons—stirring perhaps unquiet memories; taboo and half-forgotten ritual; no-touch technique for knees, long instruments for femurs. But though the need for care is paramount, there *is* need also for simplicity. The common sense of Moynihan has left us safe and easy methods which retain the service of our best auxiliary, the hand, and let its well-gloved fingers touch both joint and bone. A twenty-year experience of these measures in general surgery and in major orthopædics has made me certain that a single ritual works well in either field.

The skin as enemy.—Moynihan would not permit the outer surface of a glove to touch the skin at all—either the hands of surgeons or the skin of patients: he branded contact as a fault, however well the hands were cleaned or skin prepared. And while for many years we all have learnt to don our gloves, touching their inner surface only, the gain is often lost by using them to handle patients' skin. If we avoid this fault throughout the operation, a sterile and undamaged glove remains as sterile as a metal tool, and may, I know, "explore a knee joint . . . with impunity" (Moynihan, *British Journal of Surgery*, 1920, **8**, 29).

But gloves (as L. G. Gunn once said of cats when sutures broke) "ain't what they used to be"; so it may now be wise to smear, in case of accident, some dettol cream upon the hands

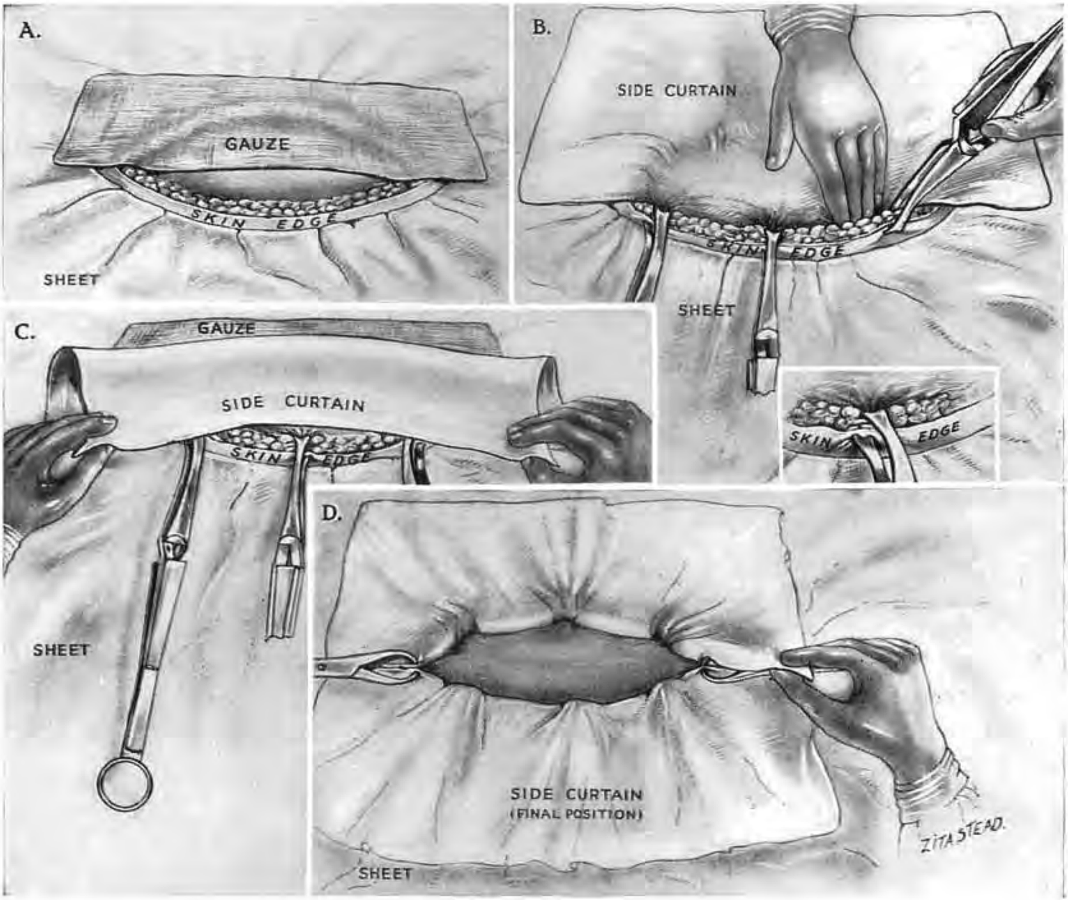

Fig. 3

Application of a side curtain. (A sterile sheet is already in place)

A. Screen the patch of bare skin at one side of the wound with a piece of gauze.

B. Lay the curtain flat on the gauze and bring the edge of the curtain to the *opposite* edge of the wound. Depress the edge of the curtain deep to the whole edge of the wound before applying clips. (That is vital ; otherwise skin will bulge between them.) Fix this depressed edge of curtain with clips so that one jaw of each clip fastens the cloth to subcutaneous tissue while the other bites directly on to the surface of the skin (see inset).

C. Lift the free opposite edge of curtain, and cover the clips by turning the curtain over through two right angles. Discard the gauze, treating it as soiled, *having touched skin*.
(The second curtain, applied in the same way, is screened from skin by the first and needs no gauze.)

D. The two curtains in position. Terminal clips can be hidden at will, as shown on the right side.

before the gloves go on.[1] Or should the skin resent it, as does mine, wear *two* pair, using cream upon the first.

(This attitude to skin implies that we discard each knife used for dividing it—with other tools that touch—and then take fresh ones to continue.)

Masks.—The parts of these that screen the nose and mouth should be impermeable. The best are made entirely of cellophane (except for fittings on the face and ears); but pockets stitched to common gauze varieties of mask will hold thin sheets of cellophane and screen effectively.

Marking the skin for final closure, though not concerned directly with asepsis, allows of perfect apposition. The scratches of a fine *round*-bodied needle should cross proposed incisions; a cutting needle is apt to leave a scar. These slight marks will help in closing any operation wound; they are essential when the parts take new position during closure, a lesson sharply driven home by suturing an unscratched case of old luxation of the shoulder.

Side or wound curtains.—The use of these is almost universal, though they are often so applied that wads of naked skin bulge into view between the towel-clips. Fig. 3 and its legend show a technique due to my former colleagues, Richard Slattery and Faïd Yusry, and I shall only touch here on the value of Michel clips for fastening these curtains. *Clips have no handles,* a special virtue when one has to curtain neighbouring incisions, say on the foot.

LONG INCISIONS

Lines of cleavage and of crease.—A recent fashion teaches that most things good or bad about incisions must be linked with the so-called cleavage lines of Langer, which Dupuytren some twenty years before exploited by proving that a cobbler's awl, though circular in section, could leave deceptive *linear* wounds

[1] A friend whose skin was harbouring staphylococci has told me that use of dettol cream allowed him to complete his operating sessions with hands and *wrists* both negative to culture tests. In this connection, too, the observation made by L. A. Weed and Jessie L. Groves at Indiana University Medical Centre is relevant. One or more gloves were found perforated at the close of almost three-quarters of the operations performed—viz. after 3409 operations out of a total 4549 (*Surgery, Gynecology and Obstetrics,* 1942, **75,** 661). There is, however, still on many sides an unashamed solicitation of infection; the septic case (apart from all emergency) is often touched, or even dressed, with naked hands by persons who will presently affect aseptic ritual—a sight that stirs the gorge of those conditioned otherwise.

in skin—using the gist of his discovery to solve an actual 'who-dun-it.'

Aside from this, however, we now are told as follows : Surgical incisions made along Langer's lines heal with a minimum of scar tissue ; incisions crossing them heal with a broad or heaped-up scar. Thirdly, that where **crease** lines exist (*e.g.*, near joints), the cleavage lines usually coincide with the creases.

Alas ! (if one may credit the accepted charts) the cleavage lines that run behind the knees and at the front of elbows fail utterly to coincide with the crease lines of flexion : in fact, they cross them. But at the present time the making of a longitudinal cut directly in front of an elbow or behind the knee is frowned on or, in current slang, declared non-U—the sort of thing Jean Cocteau (D.Litt., Oxon., *Hon. Causa*, 1956) calls "*comme-il-ne-faut-pas*." And so one sometimes wonders just how much the cleavage lines—at least in limbs—concern themselves with good, cosmetic healing.

Perhaps the flexor *crease* is after all a dominating factor ; for in the neck, when goitre surgeons cut circumferentially, they "kill two birds with one stone" : they follow there the ineluctable coincidence of cleavage lines with flexor creases—the latter latent or in being, on the neck. Not so the orthopædist who, in front of elbows and behind the knee, feels bound to let the lengthwise Langer lines go hang, and gives a crossway swerve to his incision at or near a flexor crease.

One of my growing bevy of detectives makes, I think, a comment apposite to this affair of crease and line : "Knowledge, like fruit, I guess, has to ripen before it's of any use."

For neurovascular bundles.—The use of wide approach for dealing thoroughly with nerves and vessels needs no defence, but tends to slip at times into oblivion. These neurovascular bundles are moored extensively along the limb by frequent offsets ; they are impossible to mobilise through short incisions, nor can they be explored. 'Closed' lesions of the vessels as a rule in swollen, freshly injured limbs demand a long incision ; for often they are multiple and may occur in great variety, though signs are few and point to nothing certain but the need for intervention. Then, too, a neurovascular bundle—like that behind the knee—can bar the way to an objective and must be widely mobilised before we can retract it safely.

For bones.—The long incision is essential in exposing bones. I do not know of any principle of surgery less easy to instil ;

yet on its proper application depends success with compound fractures that reach us *early*—the rule to-day aside from stress of battle. In these fresh accidents a septic outcome has, I have found, been variously viewed by those concerned. To some it was a normal happening; to some a case of surgical misfortune; to some again it seemed the sign of slipshod treatment for which they felt a plain and personal responsibility. Of late the rediscovery of Pirogoff's great finding—so useful in its proper place—that septic limbs can stink their way to health in plaster, has innocently been the source of a defeatist question: What harm if early fractures suppurate? The answer is: The curse of sepsis when it grips a bone; or (on another plane of evil), the waste of time—and beds.

We can frustrate this curse, almost with certainty, by thorough early cleansing, in company with secondary measures; so that an open fracture which has skin to cover it should normally be "simple" in a week, while those devoid of skin are rescued from the drag of suppuration. Incisions, therefore, must be long enough for us to find and clear away both dirt and damaged tissue.

If we have reason to suspect that dirt has reached the bone, then we must scrutinise the site of fracture—especially the central portion of the broken ends. For this too-frequently neglected step a cut three-quarters of the length of shaft will only just suffice, even with bones so near the surface as the tibia; and thus, if dirt ingrains the ends, it can be lightly chiselled off. But if we do not look, it is impossible to *know* these broken ends have not been soiled; and if we leave them soiled (whether from negligence or grim, extraneous necessity) we sabotage the operation. Bone, in the suspect case, will thus decide the length of our incisions: those long enough to let us bring the ends for scrutiny are long enough to let us cleanse the wound throughout.

A NOTE ON EARLY OPEN FRACTURE.—The background of a damaging remark made to me once by a surgeon, young, travelled, well-informed and capable, evoked these most unfashionable paragraphs. "Our generation," he said, "associates the treatment of compound fracture with a bad smell." This turned my thoughts again to Egypt where certain ancient Greeks, too faithfully disguised as seals, once lay in ambush and suffered terribly till rescued from the deadly stench.

These fractures were among the commonest emergencies of Cairo. Their treatment in my unit was carried out by colleagues who, since 1926, believed themselves at fault if they fell short of turning well over 90 per cent. of open lesions into clean or simple fractures. This work, I feel, deserves a record. For it seems clear to me that if some thirty years ago such high success could be achieved with soiled, subtropic fractures in patients often underfed or sapped by parasites, to-day with newer means and better nourishment the incidence of sepsis in early open fractures should be negligible—a thing I failed to note since leaving Egypt.

Our method in the Cairo unit was based on pages of Lejars'—remembered from a 1903 edition. It was enhanced by what I learnt in 1917-18 from Richard Stoney's notable results with bipp[1], dilute and harmless—another very grateful recollection.

We did not use a plaster case till 1931 for open fractures, but only splints or gutters, yet our success, considered in the light of absent sepsis and rapid union, was just as excellent without as with: it is the cleansing, not the plaster, that decides.

The cleansing of the wound and of the bone are dealt with in the text; here I shall merely stress the fact that any slackness in preparing normal skin was always paid for by an upward trend of sepsis: our best results were got when wound and skin alike were cleaned with equal thoroughness. We learnt to treat the limb *en masse*—as if for sterile operation on a joint—and, using ether first, we painted all the skin with brilliant green—a 1 per cent. solution in 30 per cent. alcohol.

The need for mild antiseptics in the wound.—No matter how well we execute the task of cleansing a wound—not forgetting the routine but economic resection of its original damaged border—our cleansing is only macroscopic, and many dirty points remain unseen. It is, I believe, for this microscopic residue that mild antiseptics have their use in recent compound fracture. Those that served best in my time with the unit (1925-36) were: (1) the dilute non-toxic bipp of Stoney's formula—well rubbed in after sousing the cleansed wound with ether; (2) a 1 per cent. aqueous solution of mercurochrome freely applied—combined, as we shall see, with bipp.

On not quite closing the wound.—In 1927—just when we felt most confident—I learnt from a septicæmic death in a long, completely successful series, never again to close the full length of these wounds; and in our lines of suture we thenceforth left an opening opposite the site of fracture. Through this inch-wide gap a wick of sterile gauze or bandage impregnated with dilute bipp reached from bone to skin. If loss of deeper tissues left dead space, we used the wick to fill the cavity. This packing of the cavity with a loose bulk of heavily bipped wick, inimical to growth of organisms, is merely an example of the old and far too much forgotten Mikulicz device for drainage; it leaves no breeding pools nor burrows for discharge to loiter in, but makes instead—all round the well-bipped pack—a film, unstagnant and unstinking, that flows directly to the surface.

We then covered the line of suture with an equally well-bipped pad, and the limb was put in plaster, leaving a long window opposite the pad. After forty-eight hours we withdrew the wick and renewed the pad.

(In thoracic non-tuberculous empyema complete drainage—unobtainable by tubes—can be got by using a Mikulicz "tampon." When mediastinal stability has been assessed a window is cut in the chest; through this the centre of a square-yard of thinly bipped batiste is invaginated to form a sac whose lumen is then judiciously distended with wide bandage till the sac fills the whole empyema cavity. There is no pocketing; pus drains from the film between sac and thorax along gutters in the gathered neck. The bandage is withdrawn a span at a time, beginning on the second day; the sac remains until it comes away unforced and virtually of itself—this last a paramount condition for success. A thickly bipped dressing over the protruding neck prevents the sucking in of air (*Lancet*, 1944, **2**, 816).

I have sometimes wondered whether this means (which works so well in the abdomen) could not be used in the chest, with, say, pulmonectomies when bronchial sealing is precarious, or as a safety valve for questionable suture lines in the œsophagus. Apart, too, from drainage, surrounding tissues might profit by a sort of restful, splinted interlude, while moving structures worked against the semblance of accustomed pressure.)

Denuded fractures.—A wide destruction of the tissues is found in certain compound fractures and leaves exposed a length of bare and broken bone. The cleansing of such wounds when dirt-ingrained, by the slow process of picking up and cutting off each bit of damaged tissue takes more time than some of these patients can well stand.

The task compares in difficulty with piecemeal cleansing at low tide of rocks spread with seaweed; when the tide flows, wide mats will rise on *pedicles* and lend themselves to clearance. Water from a tap at any place with clean supplies will serve to simulate the tide: under the stream the damaged tissues float on stalks, and these are then snipped off, in rapid contrast with the weary plucking of a sheet of scum.

The *force*, too, of the stream will help to clean the wound; its whole might is brought to bear on every part in turn by narrowing the outflow from tap or tube. This simple method —far from original but little used—was put in hand for me by Faïd Yusry in 1931.

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[1] For details of bipp, see footnote to p. 259.

Success began, I think, to smile on us one day in 1925 when I decided with my friend Handusa to rank the compound fractures with acute abdominal emergencies. That put their treatment in the able hands of five successive colleagues—Ahmed Handusa first, then Edward Sadek, Faïd Yusry, Lotfy Abdelsamie, Mohammed el Zeneini. When I see better results than theirs in open fractures on as large a scale with any other method I shall wish to try it.

For muscles.—We need a long incision, too, for mobilising certain muscles—the wad of bellies, notably, that screen the lateral face of radius. This wad takes origin above the elbow; the knife must therefore follow it and reach well up the *arm* to let us view the radius widely in the forearm.

OPENING DEEP FASCIA

Division of the fascial envelope needs something of the care we spend on dura mater; for otherwise we plough the muscles, wreck planes of cleavage, and even wound a shallow-lying popliteal nerve or radial vessel—in swollen limbs especially.

One useful method is to grasp the fascia with forceps and make a cut to introduce the tip of Mayo scissors. The tip keeps close against the fascia and opens slightly on the flat; it then alternately, in little steps, advances and divides. If it goes far enough to rip the envelope " in one," the contents, too, are ripped.

MEASUREMENTS

Those damned dots.—Lord Randolph Churchill.

Throughout this book a use is made of fingerbreadths, thumbbreadths and handbreadths [1]; sometimes of spans, which may be generous or otherwise. They have advantages: the means of measuring are always with us, and those I shall describe have stood the test of years. Their own variety appears to chime with the vagaries of anatomy that mock our text-book decimals—a consonance I always find amazing; for students, surgeons, patients and cadavers vary remarkably in size and shape.

[1] The hyphens are left out; they may be dropped in compound words (says Fowler) as soon as the novelty of the combination has worn off. And here this argument applies: Hippocrates employed the fingerbreadth, and this, no doubt, he " went an' took—the same as us."

SECTION I

EXPOSURES IN THE UPPER LIMB

. . . et ayme plus souvent à les saisir par quelque lustre inusité.—MONTAIGNE.

OUR first attack accords with the caprice of wounds. Choosing the arm we " pinch it to the bone " by an unwonted aspect and thus obtain the windfall of a type exposure.

This comes conveniently and well equipped to illustrate the Introduction. We find at once the means for wide inclusive access: a muscle we can move and steer by; a V, a half-sleeve and seam, a bucket-handle; useful mobilities and friendly dispositions. But terminology has seen to it that these auxiliaries (like persons in the fairy-tale) are neutralised and checked from full cooperation. They are, in fact, bewitched.

APPROACH TO THE WHOLE BACK OF THE HUMERAL SHAFT EXPOSING FROM BEHIND THE NEUROVASCULAR BUNDLES OF THE ARM

His opinion, in this matter, was, That there was a strange kind of magick bias, which good or bad names, as he called them, irresistibly impressed.
—TRISTRAM SHANDY.

The three heads of triceps.—A blight of terminology conceals the simple plan of triceps, a plan which is the key to this approach. And so we have the queer, ingrained confusion of a long head (unquestionably long but medial too) companioned by a head *called* " medial " or " inner " which has—in man at least—no title to the name. For the main bulk of so-called " medial head " springs, not as one might think, from medial parts of humerus, but (as Albinus notes)[1] from the whole breadth: and, what is more, the head lies covered by its fellows. A curious example of nomenclature—amusing, if its " magick bias " were not a drag impressed on intervention.

When once we break that spell, the plan of triceps shows in full simplicity: two heads—the long which leaves the scapula, the lateral which springs from humerus—are *superficial*. And these heads joining V-wise form a loose half-sleeve that shrouds the third (Fig. 4). This third head, therefore,—miscalled the "inner" or "medial"—is certainly the *deep* head of triceps.[1]

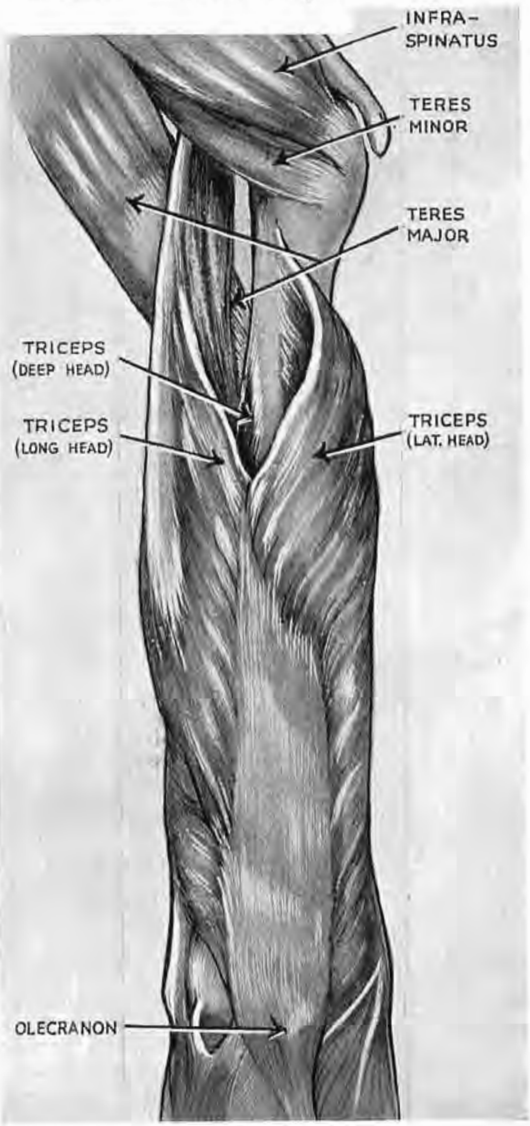


Fig. 4

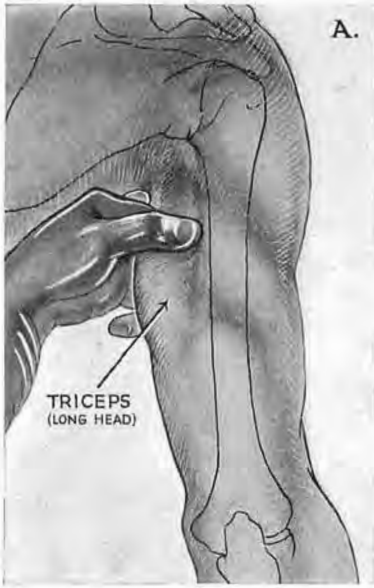
The three heads of triceps

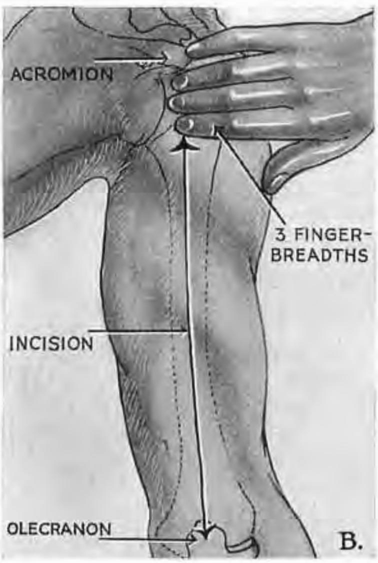
The superficial heads (the long and lateral) meet in a V; they spread and form a loose half-sleeve almost completely hiding the third and *deep* head of triceps (called perversely 'medial' or 'inner').
The deltoid has been removed. Note how it would slope across and cover the proximal part of the lateral head.

Viewed in this way the whole muscle becomes a kind of wish-fulfilment: the very details of anatomy are on our side.

[1] Since that was written I found my view already held by a professional anatomist who long ago had called the head *deep*. Use of the term *medial head* "is apt," he wrote, "to give rise to some misconception of its nature and position" (T. H. Bryce (1923), in Quain's *Elements of Anatomy*, London, 11th edition, vol. iv, Part II, p. 124). No echo followed this gentle understatement; but in an old number of the *Sunday Times* I came (with some surprise) on the appropriate remark: "If Dons," it quoted, "are not even accurate, what the hell are they?"

Albinus saw the facts quite clearly; the magnificent folio of *Tabulæ* from Dobbin's great collection shows the deep head displayed by the cutting away of its two companions "quibus subjacet"; and the note on Fig. 7, tab. XIX (1747) adds: "Et initio suo occupat amplitudinem ossis." Albinus calls the deep head *brachialis externus*, the counterpart for him of our plain brachialis—a muscle which he qualifies *internus*. (This seems confusing till you let your arm hang naturally down; then you will see the force of his description.) So, for Albinus the triceps has two layers: (1) a superficial, bicipital layer whose long head is our long head and whose short head is our lateral; (2) a deep layer.





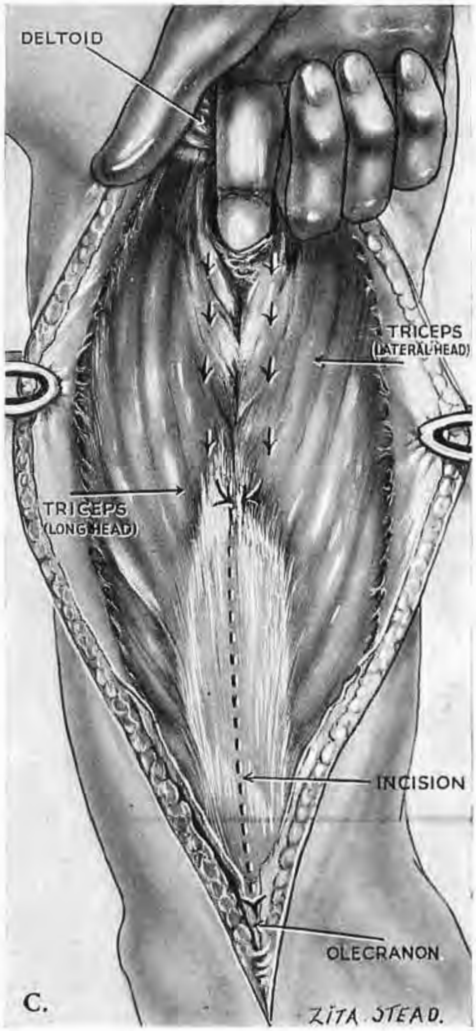


Fig. 5

A. **Finding the long head of triceps.**—This is your guide (1) for incising the skin ; (2) for finding the V-shaped opening of the half-sleeve. Grasp it where it goes from scapula to arm and move it on its stationary neighbours (deltoid and lateral head). Divide the skin and fascia close beside its outer edge ; the entrance to the sleeve lies *there*. (If you lose touch with longus you tend to lose your way between deltoid and lateral head.)

B. The **skin incision** begins beside the outer edge of the long head three fingerbreadths distal to the acromion. It goes down to olecranon.

C. **Opening the seam of the half-sleeve.**—Keep the finger close to the outer side of the long head and enter the V. Ease the loose sleeve off underlying structures. Begin the separation of long and lateral heads gently with the finger ; continue with the knife, dividing the oblique fibres of lateral head at their attachment to the tendinous lamina which is developed—as Albinus notes—by longus in the depth of triceps. This lamina looks forwards and out (see Fig. 6).

THE OPERATION

Finding the long head.—With the patient face-down we abduct the arm and look first for the long head of triceps, our guide in this approach.[1] Luckily the long head is far more mobile than the neighbouring deltoid and lateral head, and we need merely grasp and move it in order to distinguish it from either (Fig. 5, A).

Incision.—This follows the outer edge of the long head beginning three fingerbreadths below the acromial angle and going straight down to the olecranon (Fig. 5, B). When the skin has been divided, we shall again grasp and move the *proximal* part

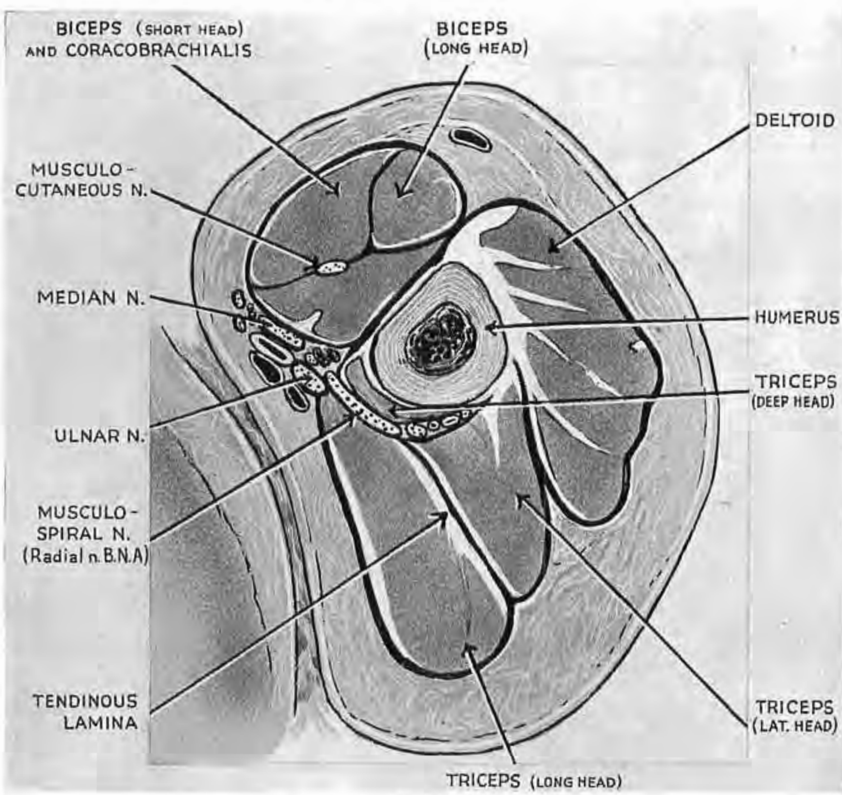


Fig. 6

The tendinous lamina developed by the long head

It marks the seam of the half-sleeve. Note, too, how the ulnar nerve lies at the sharp, anterior edge of the long head. This guiding edge is separated from the nerve by thin fascia. Note, too, the small tongue of deep head of triceps that always separates the musculospiral nerve from humerus (see legend to Fig. 9). This figure (taken from Poirier and Charpy, 2nd Edn., 1901, Vol. II, fasc. 1, p. 97) also shows the labile relation of the ulnar nerve, which here lies *lateral* to brachial vessels and median nerve—instead of medially. (See text, p. 22, and Fig. 7.)

[1] The V-shaped junction of the long and lateral heads may show as a depression on a thin subject with the arm abducted in the face-down posture.

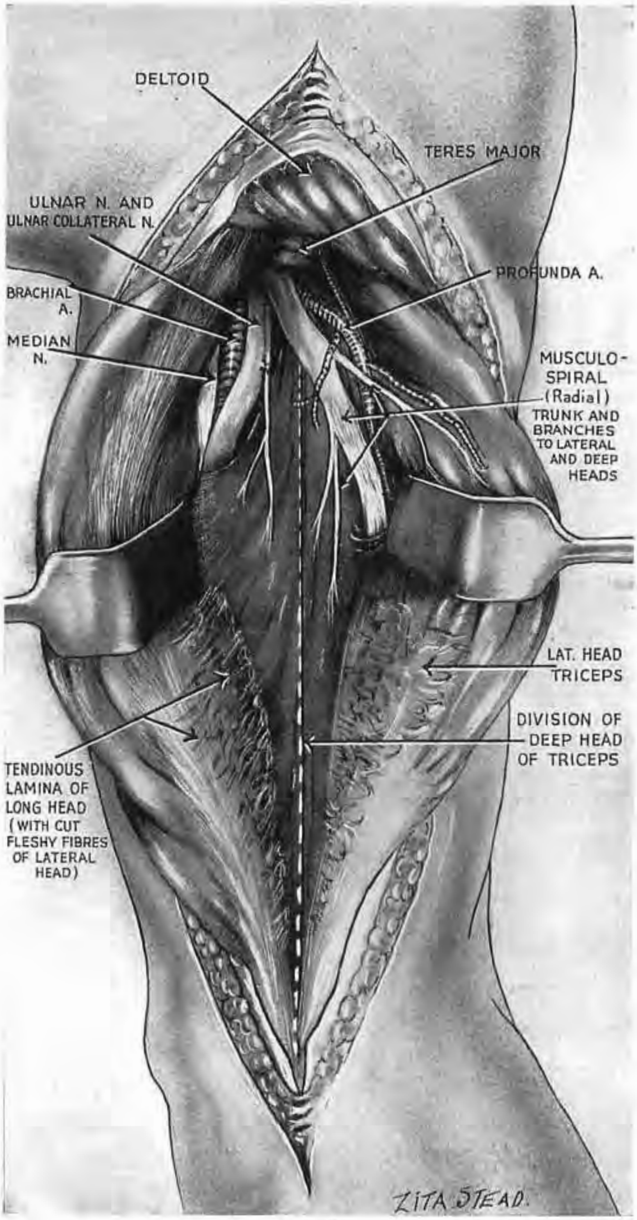


Fig. 7

The half-sleeve opened

The seam is ' ripped ' : the two halves of the sleeve (the superficial heads—long and lateral) are separated, exposing the slanting neurovascular bundle. This consists of musculospiral nerve and profunda vessels ; it crosses the deep head, which clothes the humerus behind much as brachialis clothes it in front. Some four fingerbreadths of the main neurovascular bundle (ulnar and median nerves, brachial vessels) show in the space between long head and deep. Note the useful gap between the two parallel musculospiral twigs, leaving room to split the deep head. (The medial twig is the ulnar collateral.) Note and take care of the branch to the lateral head of triceps. (For the unusual lie of ulnar nerve, see p. 22.)

of the long head, so that we may open the deep fascia close to its outer side. Here the finger will enter the V-shaped meeting-place of long and lateral heads, and working down in contact with the long head will presently hook into the loose half-sleeve (Fig. 5, c). But we must be sure to keep in contact with the guiding belly; the finger otherwise may open the wrong plane and lose its way between lateral head and overlying deltoid. That is the first pitfall.

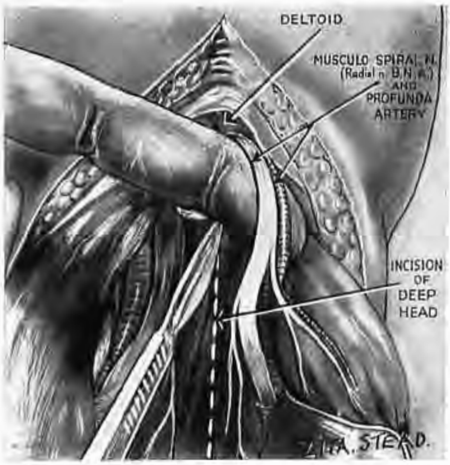


Fig. 8

Raise the oblique bundle like a bucket-handle, *working from below*, and lift it clear of the deep head. The deep head can then be split lengthwise from end to end. (The branch to lateral head must be picked up with the main bundle; it is likely to be cut if the bundle is mobilised from the proximal edge.)

Separation of the superficial heads (the long and lateral).—A finger hooked into the V-shaped opening lifts the sleeve from what lies under, and then begins to rip the seam that marks the meeting of these heads. But soon we need a knife (Fig. 5, c), for fleshy fibres of the lateral head slope down to join a shining lamina which the long head develops in the depth of triceps (Figs. 6 and 7).[1]

The bright face of this oblique 'intrinsic' tendon is the plane for clean separation.

Opening the half-sleeve we find the large bundle consisting of musculospiral nerve (the radial of B.N.A.) and profunda vessels, a slanting band thinly divorced from bone by the deep head of triceps (Fig. 7). And if we raise the bundle gently like a bucket-handle and loop it back (Fig. 8), we then can pass the knife beneath, split the deep head lengthwise and reach almost the whole shaft from behind (Fig. 9, A).

Mobilising the musculospiral bundle.—Begin at the distal edge of the bundle on the medial side of the wound and work outwards. The lateral head of triceps receives a large nerve which runs a more transverse course than its parent trunk, and so is widely separate from the slanting bundle (Fig. 7). We must not

[1] This detail was familiar to Albinus: "It is impossible to show in this figure"—6 of tab. XIX—"how the long head develops (*efficiat*) a wide tendon on the side next (*a parte*) the lateral head, and how fibres of the lateral head reach it—just as on the *surface* of triceps (*extrinsecus*) fibres of the long head reach the lateral." (I have used our term "the lateral" for the head Albinus calls "the short.")

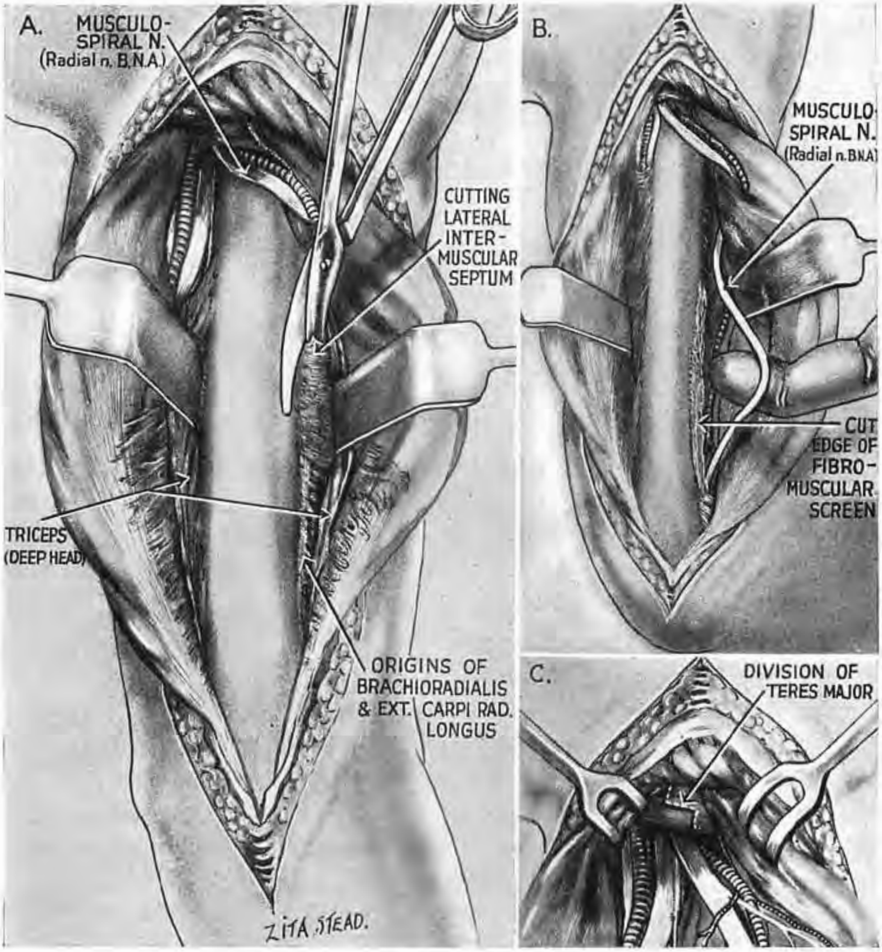


Fig. 9

A, B, and C. **The humeral shaft exposed from behind with the musculospiral (radial) nerve**

The two halves of the deep head of triceps have been peeled off the bone and retracted, exposing the lateral intermuscular septum. This retraction brings the small tongue of deep head, which always parts musculospiral from bone, round *behind* the nerve (B and Fig. 6).

For *distal* extension of the musculospiral exposure (A and B), divide the lateral septum plus the thin attachments of brachioradialis and extensor carpi radialis longus on its anterior face ; all three of these together screen the nerve.

For a more *proximal* extension (C), divide the flat band of teres major plus latissimus tendon. (Note the Z-shaped cut for sound repair.) Adduct the arm to relax the musculospiral which can then be drawn out like a loop (as in B).

fail to loop the branch and bundle up together (Fig. 8), for if we overlook the branch, it will most probably be cut—a frequent fault in making this exposure. (An ascending leash from profunda vessels may cross the field obliquely and go deep to deltoid (Figs. 7 and 10); sometimes it is large.)

Splitting the deep head.—Even the nerves to this part of triceps befriend our purpose: *the inner half* of the deep head is supplied by the fine ulnar collateral, a musculospiral (radial) twig that is often closely bound to the ulnar trunk and was long mistaken for a true ulnar branch (Fig. 7). This twig arises high in the axilla and enters the deep head two handbreadths distal to the acromion. *The outer half* has a stronger parallel twig (which also innervates the anconeus). It arises either with the branch to the lateral head or independently, and like the ulnar collateral enters the deep head two handbreadths below the acromion; thence it runs in the posteromedial part of the belly. Thus we can split the deep head between two longitudinal branches (Figs. 7 and 8). But the knife should keep close to the more lateral of these and aim for the olecranon; otherwise we may injure the ulnar nerve which sometimes bends outwards before reaching the elbow.[1]

It was noticed by the friendly critic of a first reprint that in Fig. 7 the ulnar nerve near the top of the wound is shown as lying *lateral* to brachial artery and median nerve. That was the true position in the specimen when the drawing was made. The reason for this lay, I believe, in the presence of a common type of ulnar collateral branch of radial nerve that fellow-travels briefly, or (to quote Professor Last) 'hitch-hikes' in the substance of the ulnar trunk.

Anticipating Fig. 8, the radial nerve (plus the profunda brachii vessels) had been tentatively looped with a finger *before* Fig. 7 was completed, and so had pulled upon its ulnar collateral branch, which thus drew the ulnar trunk out to a lateral position—where it awaited the artist. My friend T. P. Garry has therefore called this neural arrangement "an error of retraction." (The orthodox medial position of the median trunk at the lower part of the segment seen in Fig. 7 supports this explanation.)

Labile relationship.—A quite different condition is apparent in Fig. 6 (which is an accurate copy of one made for the text-book of Poirier and Charpy some fifty years before my Fig. 7). Here,

[1] *This curve is dangerous.* I have seen the ulnar trunk divided during the exposure; but fortunately, so far, in the dead.

too, the ulnar nerve lies *lateral* to the median—*and* to the brachial veins and artery. But Poirier's specimen comes from an undissected cadaver, hardened, as the figure shows, while the arm lay pressed against the thorax. This pressure, in virtue of the natural mobility of main neurovascular structures at midarm level, seems to explain the anomalous relations of Fig. 6. Such relations, which come with diffuse pressure through skin and go with its relief, are *labile* relations. I have found them at midarm level in cadavers with orthodox neural patterns.

The posterior approach to the humeral shaft resembles that for exposing the anterior, homologous face of the femur There, too, a loose half-sleeve of muscle covers a deep head crossed by a neurovascular bundle; there, too, we rip a seam, loop the bundle and split the deep head to reach bone.

EXTENDING THE POSTERIOR VIEW OF THE MUSCULOSPIRAL (OR RADIAL) NERVE.[1]—When the outer half of the deep head is fully raised from the back of the humerus the lateral intermuscular septum comes into view and—in company with the flat thin origins of brachioradialis and extensor carpi radialis longus—screens off the musculospiral nerve which goes in front. Divide this fibromuscular screen as close as possible to bone and so avoid the twigs to muscle (Fig. 9, A); then relax the nerve by adducting the arm (Fig. 9, B). That will let us deal with three more inches of musculospiral trunk, a surplus gain which often saves the nuisance of making fresh incision to find and liberate the nerve in front.

At the proximal part of the wound a similar length of musculospiral can be won by dividing the compound band of latissimus and teres major tendons, after easing the ulnar and musculospiral nerves safely away from its anterior face. A Z-shaped section of this band (Fig. 9, C)—made tense by abducting the arm—will favour strong repair.

THE MAIN NEUROVASCULAR BUNDLE OF THE ARM SEEN FROM THE BACK.—The brachial vessels and median nerve are easily explored in this posterior approach, for when we separate the

[1] "Musculospiral" appears again as an alternative. The recent imposition of "radial" on stem and branch alike has robbed the word of meaning for those acclimatised to both the previous terminologies. And some (who weathered each) would willingly agree with Pater that since "all progress of the mind consists for the most part in differentiation . . . it is surely the stupidest of losses to confuse things which right reason has put asunder, to lose the sense of achieved distinctions."

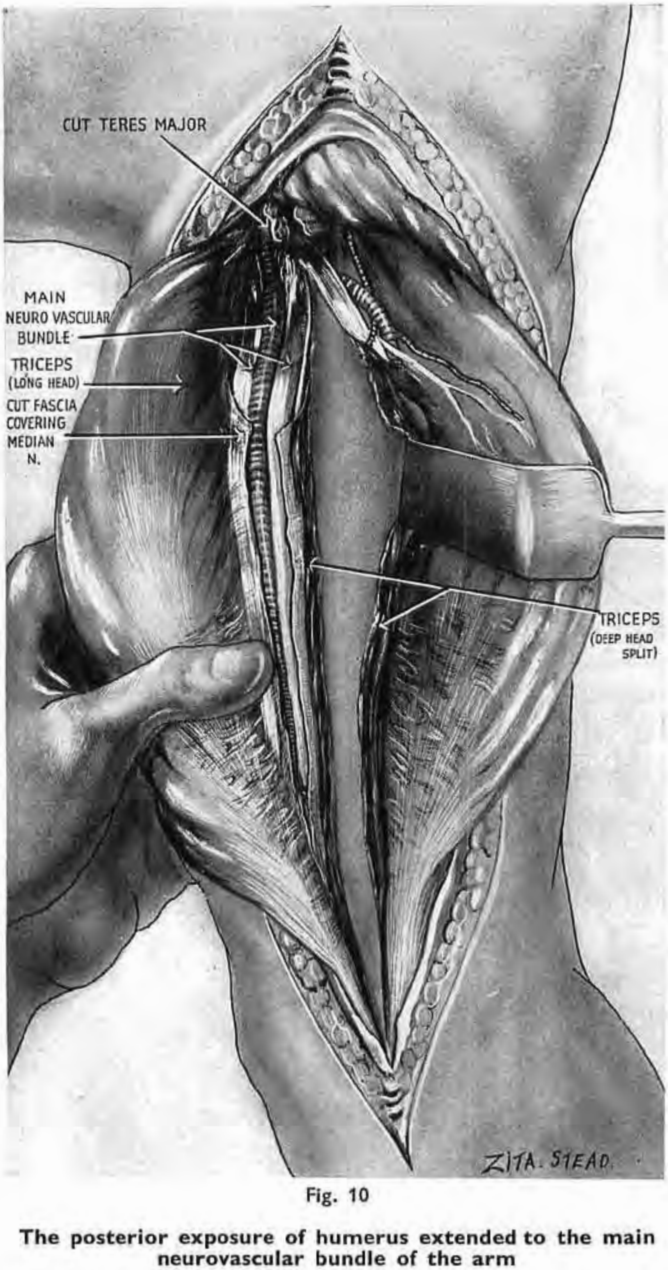


Fig. 10

The posterior exposure of humerus extended to the main neurovascular bundle of the arm

Separate the long head from the deep, and thus enlarge the upper space through which the bundle is already visible ; a screen of fascia must also be divided. Grasp the arm as in the figure (but through towels). Work the bundle up into the wound, using your finger-tips to bring it round the inner side of the deep head. (The median nerve sometimes sticks to the front of the brachial artery.) Access is easy and room sufficient to explore the bundle and recognise its frequent abnormalities (high division of the artery, etc.)—a further merit of the long incision.

long head of triceps fully from the lateral, some 4 in. of main bundle are seen in the upper part of the field (Fig. 7). But farther down the arm the bundle is first veiled by a sheet of fascia and afterwards concealed by the deep head of triceps, in front of which it rests. Turn then to this deep head and separate the long head from it right down the arm. Through the covering towels grasp and gently squeeze the inner side of the arm in such a way that the tips of the fingers will bring the bundle round the inner side of the deep head and up into the wound. Thus we can deal from behind with the great anterior nerves and vessels (Fig. 10).

APPROACH TO THE FRONT OF HUMERUS WITH EXTENSIONS TO ITS JOINTS TO THE FOREARM AXILLA AND ROOT OF NECK

During a surgical exposure important neurovascular structures are spared in one of two ways: either we seek them out for protection, or else avoid them completely. So, in our access to the back of humerus we find the musculospiral nerve and loop it clear, whereas with *frontal* intervention on the shaft, the nerve will—if we wish—remain concealed and undisturbed. And this exposure of the front of humerus provides, as we shall see, a base for exploration of the parts at either end—the joints, axilla, neck, and forearm.

ANATOMY

The *proximal* part of the bone is concealed in front by deltoid fibres coming from the lesser curve of clavicle (Fig. 11); the muscle forms a thick unyielding cowl which gives when pulled aside a grudging revelation of bone and shoulder joint; and that will often be the last successful thing it does. So, for a *wide* approach we mobilise the cowl in front and turn it harmlessly away.

Clothing the *distal* reach of shaft are longitudinal fibres of brachialis belly whose outer flank, left free of biceps, comes to the

Fig. 11

The deltoid cowl whose front must be swung back for wide access to the top of shaft and to the shoulder joint. (*Lateral* incisions that split the deltoid threaten the circumflex nerve.)

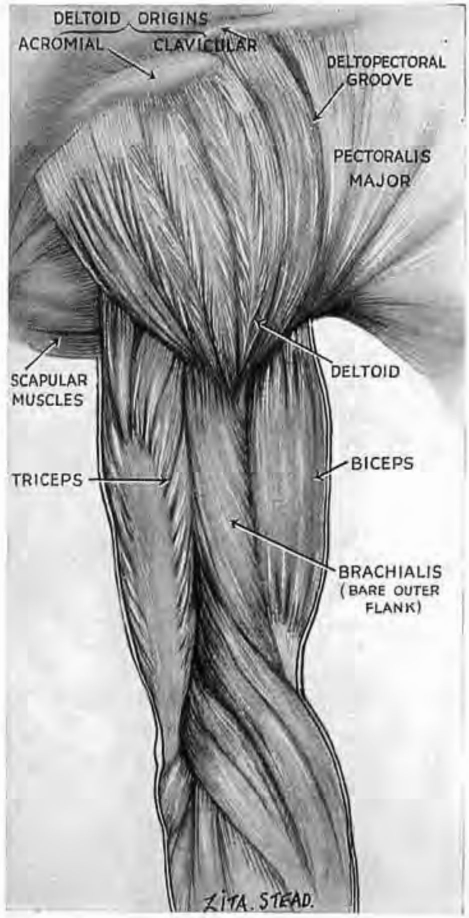


Fig. 12

The wide, bare *outer* flank of brachialis alone separates skin from shaft in the distal half of the arm (see also Fig. 13).

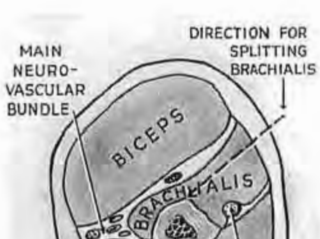


Fig. 13

Fig. 13

Cross-section through mid-third of arm, showing the outer flank of brachialis which is bare of biceps. This flank is split in the direction of the pointer to expose the distal half of humerus in front. The cut slopes in to reach the *middle line* of shaft. The musculo-spiral is safe.

surface in surprising width (Fig. 12). Here, then,—on the outer side of the arm—a single muscle (with its fascial coat) separates skin from bone; and here we shall attack the shaft through this uncovered flank of brachialis (Fig. 13).

The musculospiral (or radial) nerve.—The solid V of deltoid insertion fits down into a hollow V of brachialis, behind whose rearward limb lies the musculospiral nerve (Fig. 14); thus, we detach the limb (or separate its fibres) to find the nerve infallibly—a fingerbreadth below the deltoid eminence. But that is as we wish: the nerve need not be seen at all.

Fig. 14
Anterolateral view of the humerus showing how the solid V of deltoid insertion fits into the hollow V of brachialis. The musculospiral (radial) nerve lies behind the outer limb of brachialis V and can be found a fingerbreadth below the apex of the deltoid eminence (see also Fig. 23).

The *cutaneous trunk of musculocutaneous* curves forward at the outer edge of biceps just where the belly joins the tendon of insertion (Fig. 15). One of the outer cutaneous filaments is likely to be cut in the upper third of the forearm, though care will leave it running like a thread across the wound. (Main musculocutaneous branches to muscle are high up under cover of the inner part of biceps belly.)

The *cephalic vein* which follows the outer border of biceps and the inner border of deltoid enters the deep fascia in the lower third of the arm. It receives two or more lateral tributaries which must be divided. A humeral branch of the thoracoacromial artery accompanies the vein in the deltopectoral groove, and gives twigs to both muscles; the knife, therefore, cutting down on bone, should keep clear of this vascular gutter (Fig. 15) and go instead through fibres of the deltoid that form its outer lip.

From these facts it appears that our incision to expose the front of humerus will skirt the outer side of the cephalic vein—below, where it follows the outer edge of biceps; above, in the deltopectoral groove. So we shall keep the knife a modest fingerbreadth *lateral* to the course we map for the vessel (Fig. 15). In the distal reach, however, no mere line will always guide the surgeon; fat or swelling may affect disorientation, and I have made (and often seen) the slip of

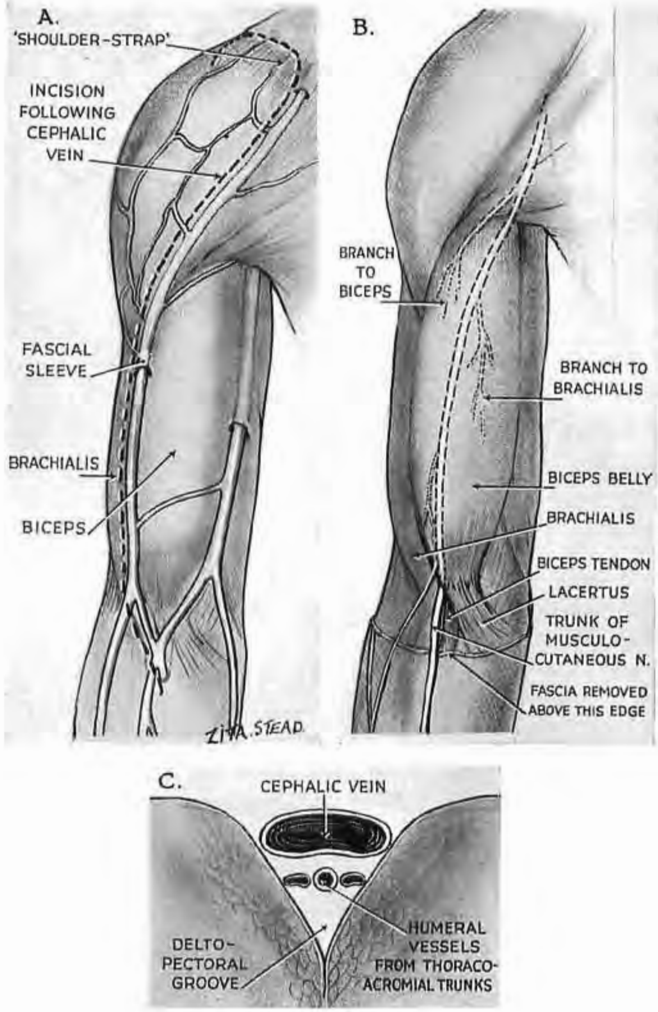


Fig. 15

A. The cephalic vein skirts the outer edge of biceps and the inner edge of deltoid. Incisions to expose the front of humerus follow the vein along its outer side. The broken line *above* the delto-pectoral groove maps out the arching part, or 'shoulder-strap.'

B. Note how the chief cutaneous trunk of musculocutaneous appears where biceps belly joins with biceps tendon.

C. Cross-section showing that the deltopectoral groove is a vascular gutter. We shall avoid it and cut lengthwise through its deltoid lip to reach the bone.

cutting through the biceps belly in mistake for brachialis flank. We therefore grasp the front of the lax anæsthetised arm (Fig. 16) and move the free biceps belly across the fixed mass of brachialis. *Then* we can locate the outer edge of biceps and with it the cephalic.

We shall see, in a moment, how to find and follow the course of the deltopectoral groove in exposing the proximal part of humerus.

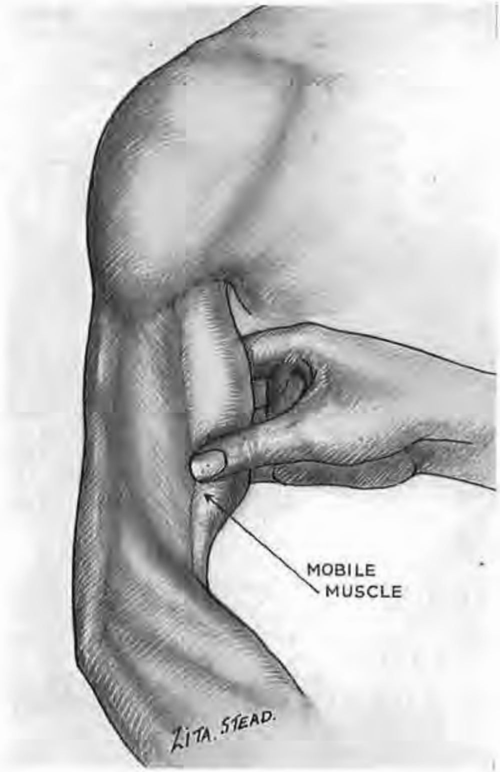


Fig. 16

Find the edge of biceps by moving its mobile belly across the fixed mass of brachialis. With this guide we can (1) place our skin incision for the distal part of the shaft a fingerbreadth from biceps ; (2) avoid the cephalic vein ; and (3) find the flank of brachialis, which (with its fascial coats) alone separates skin from shaft. This flank we shall split, directing the cut to the *midline* of humerus (see Fig. 13).

Fig. 17

The incision originally described for humeral exposure. The crooked proximal part (designed to give room to mobilise the clavicular origin of deltoid) is now replaced by a 'shoulder-strap' (see Fig. 18). The figure is retained to show the useful 'step-down' at the arrow which marks the acromio-clavicular joint.

THE PROXIMAL PART OF HUMERUS AND THE SHOULDER JOINT

The incision I once used for this exposure was acutely angled at the outer third of the clavicle in order to give plenty of room : first, for mobilising the deltoid cowl and turning it out of the way ; then, at the close of intervention, to allow easy fastening of the cowl back into place (Fig. 17).[1] But crooked cuts in skin have three

[1] *British Journal of Surgery*, 1924, **12**, 84.

faults: they are troublesome to fit with side-curtains; they are troublesome to close, and thirdly, they compromise healing. For many years, therefore, I have used incisions that cross the shoulder archwise from front to back (see *Irish Journal of Medical Science*, 1927, p. 634).

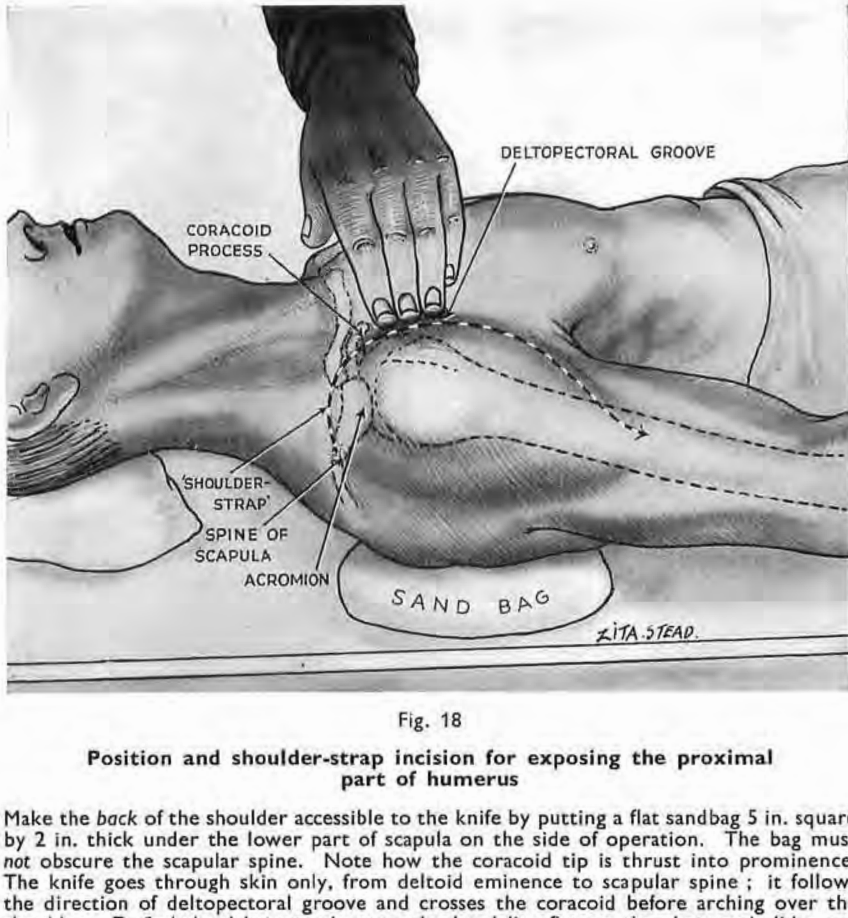


Fig. 18

Position and shoulder-strap incision for exposing the proximal part of humerus

Make the *back* of the shoulder accessible to the knife by putting a flat sandbag 5 in. square by 2 in. thick under the lower part of scapula on the side of operation. The bag must *not* obscure the scapular spine. Note how the coracoid tip is thrust into prominence. The knife goes through skin only, from deltoid eminence to scapular spine; it follows the direction of deltopectoral groove and crosses the coracoid before arching over the shoulder. *To find the deltopectoral groove* the hand lies flat on the chest and slides out over the lax front of pectoralis major. The tips of the fingers strike the firm, oblique edge of deltoid; the groove lies deep to them.

Position.—Care is required to make the *back* of the shoulder accessible to the knife. The patient lies with a flat sand-bag, 5 in. square by 2 in. thick, under the *lower* part of the scapula on the side of operation. The bag lifts the shoulder sufficiently to show the scapular spine, and also thrusts the tip of the coracoid process forward into helpful prominence (Fig. 18).

The shoulder-strap incision.[1]—If we confine exposure either to the joint or the proximal part of humerus, the 'shoulder-strap' descends no farther than the distal end of deltoid; so we shall first locate the deltopectoral groove, whose course the knife will follow. Sliding the fingers out towards the limb across the hollow face of pectoralis we touch a firm obliquity of deltoid edge (Fig. 18). The groove is there, felt by the finger-tips. The knife—which cuts no deeper than subcutaneous fat—will follow up the groove to reach the tip of coracoid; then it will cut straight on over the shoulder down to the level of the spine of scapula—or, of course, in reverse, according to the side of the limb, or manual convenience (Fig. 18).

Open the deep fascia along the whole length of groove close to its outer edge and look for the cephalic vein which occupies its channel. The knife can then avoid the groove (with all the vessels it contains) and split instead its deltoid margin lengthwise from end

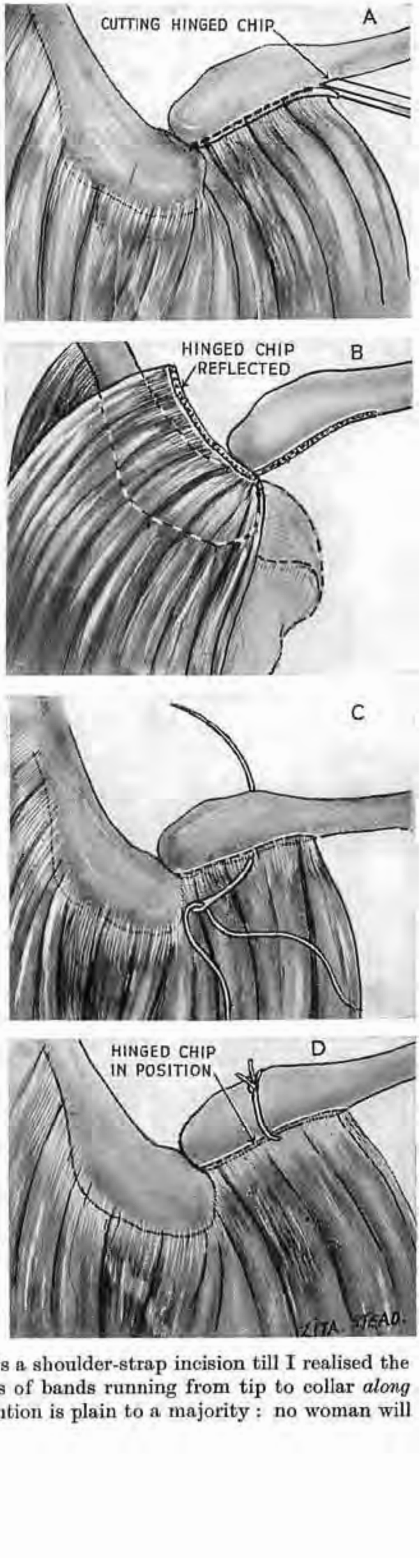


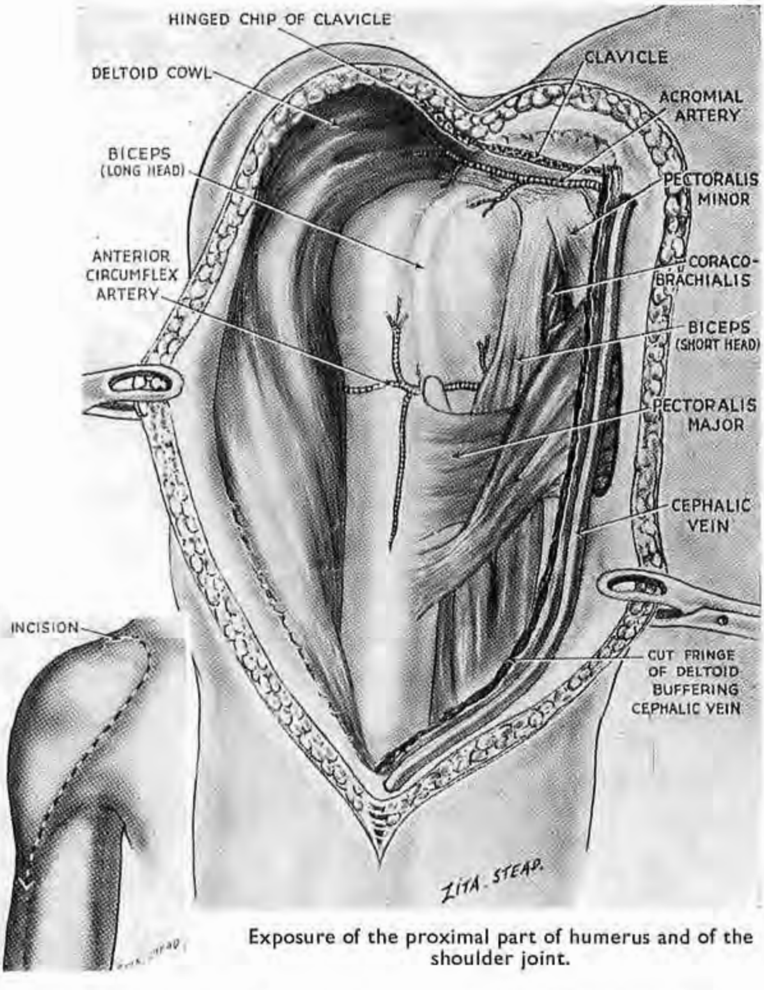
Fig. 19

Mobilising the front of deltoid

After reflecting skin, turn the deltoid out on a hinged chip cut from the lesser curve of clavicle, A and B. The deltoid origin can be reconstructed with a single ligature passed on a large curved needle, C, and tied, D. Note how the chisel—seated on its *bevel* to prevent undue penetration—cuts out as far as the acromioclavicular joint, marked by a 'step-down' (see Fig. 17).

[1] I had ventured without hesitation to call this a shoulder-strap incision till I realised the adjective came from a word used sometimes of bands running from tip to collar *along* the shoulder. Let the term stand; my intention is plain to a majority: no woman will question it.

to end. This useful detail—due to G. A. Mason (*British Journal of Surgery*, 1929, **17**, 30)—divides a negligible strand of muscle from its nerve. A small reflection of the shoulder skin gives access to the piece of deltoid that springs from the outer third of clavicle.



Exposure of the proximal part of humerus and of the shoulder joint.

Mobilising the front of the deltoid.—Divide the fascia and periosteum on the upper face of this outer third near the front of the bone. Then detach a mere shaving of the edge that carries the deltoid origin. If you are right-handed stand ' below ' the level of the patient's shoulder on his right side ; ' above ' it on his left.[1] Use a chisel and cut out as far as the acromioclavicular joint

[1] Or, if you prefer, let your stance in respect of the right shoulder be caudad : of the left, cephalad.

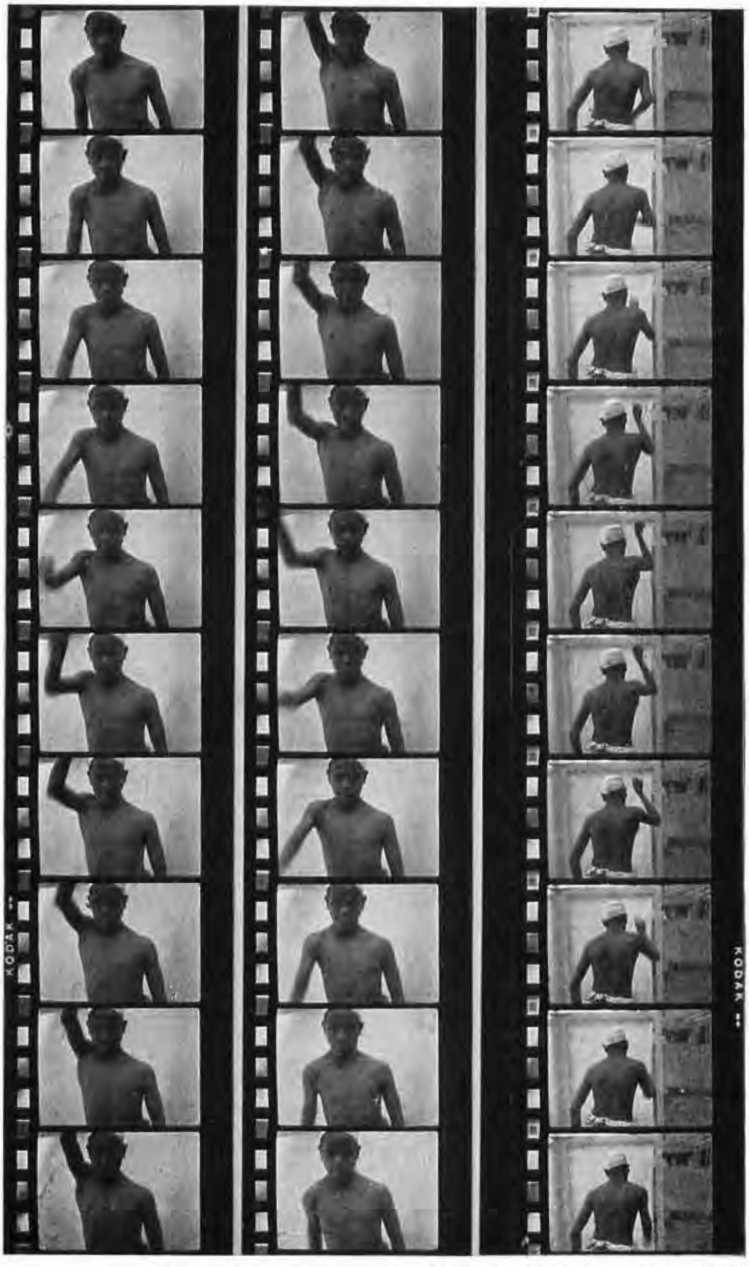
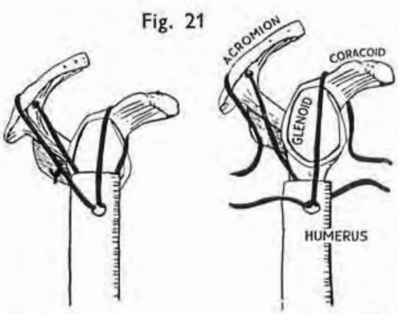


Fig. 21



To show the function of a limb after the deltoid has been mobilised and reconstituted. In this case the proximal fifth of humerus was resected for tumour, and the shaft slung with fascial strips to the scapula (see inset). Ten years later the function remained excellent. The left and middle columns are consecutive pictures from a film ; the patient, who worked in brass, raises his right arm, keeps it raised, and then lowers it. The right-hand column shows a complete hammering movement.

(Figs. 19 and 20). It is very easy to cut deep into clavicle and so remove too much bone. Seat the tool therefore on its *bevel*, and use it—like the blade of a carpenter's plane—to separate the edge only (Fig. 19 A).

The front part of the deltoid cowl can now be turned out on a hinged piece of clavicle, like a curtain on a rod. But the wide prospect we gain in this way is disappointing at first sight if we forget the spread of bursa that remains to mask (and be removed from) our objectives (Fig. 20).

After dealing with bone or joint a single suture passed through the muscle and round the clavicle with a large curved needle will lash the small piece of bone back into place and so reconstitute the deltoid origin (Fig. 19).[1] (The bony chip which carries deltoid need by no means be unbroken ; I have often cut instead a band of mere contiguous flakes ; and these united quickly with the clavicle, leaving the deltoid function quite intact.)

THE DISTAL PART OF THE HUMERUS (BELOW THE DELTOID LEVEL)

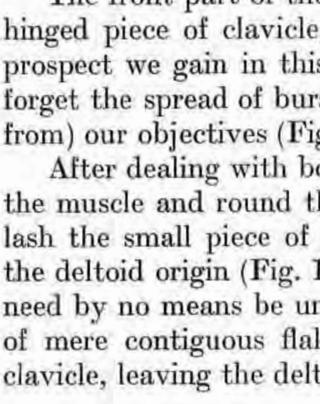


Fig. 22

Cross-section through mid-third of arm, showing the outer flank of brachialis which is bare of biceps. This flank is split in the direction of the pointer to expose the distal half of humerus in front. The cut slopes in to reach the *middle line* of shaft. The musculo-spiral is safe.

Guiding our incision by testing for comparative mobility (Fig. 16), we keep the knife a slender fingerbreadth lateral to the edge of biceps, and so respect the vein ; then we continue four finger-breadths into the upper third of the forearm, curving a little in towards the middle line. Here we must open deep fascia with extra care, especially in swollen forearms. The swelling seems to thrust the radial vessels (which are, I notice, often slit in normal limbs) still farther into danger. Surgeons, too, will take a pride in rescuing the lateral cutaneous twig of musculocutaneous which runs in surface fat (Fig. 15). A longitudinal cut is then directed through the bare outer flank of brachialis, which we identify again by moving biceps

[1] I still describe this way of mobilising and reconstituting the deltoid origin, which served me well through twenty years in dealing with the following conditions : old subcoracoid luxations ; osteoclastoma of the humeral head treated by resecting the proximal fifth

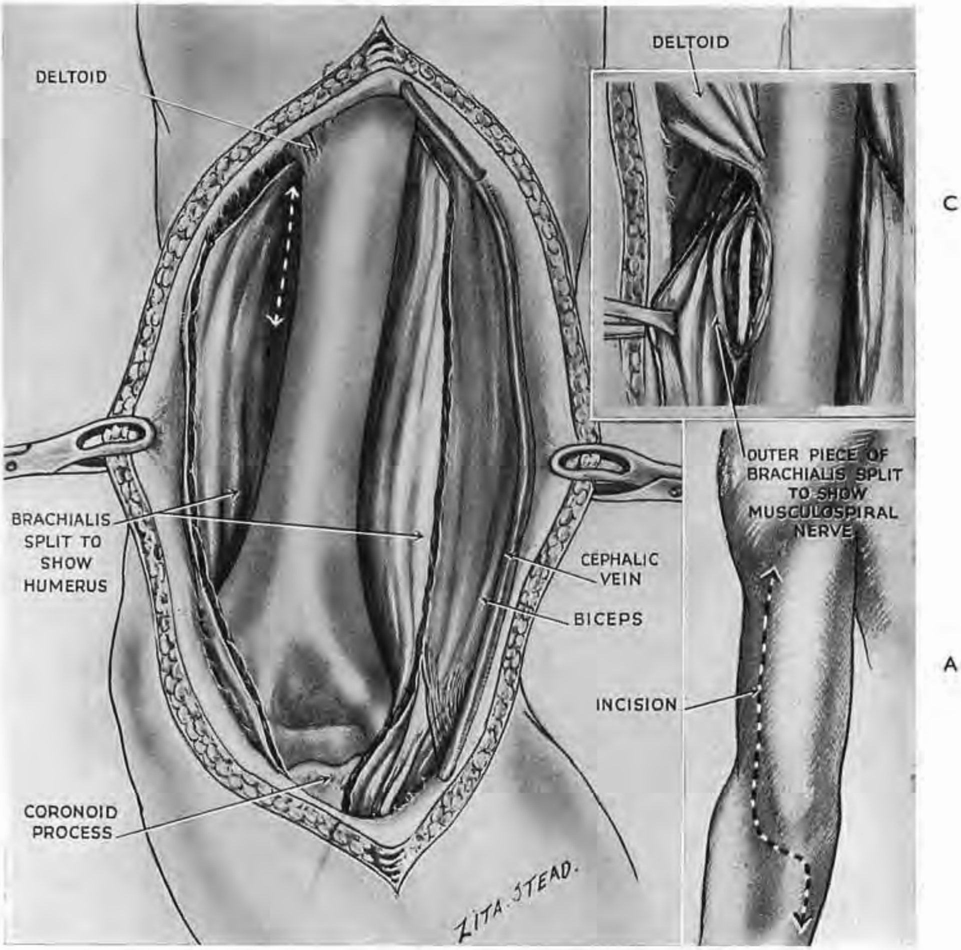


Fig. 23

Distal exposure of the humerus

A. The skin incision. B. When we have split brachialis as in Fig. 22, a partial flexion of the elbow transforms the split into a wide and shallow wound. If exploration of the elbow joint is not required, check the cut two fingerbreadths above the epicondyles. Musculospiral meanwhile is safe and out of sight. Should you wish to find the nerve, a touch with Mayo scissors parts the screen of brachialis one fingerbreadth below the deltoid eminence (B and C).

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of the humerus and suspending the rest with fascia to coracoid process and acromion (see Fig. 21, from the *Irish Journal of Medical Science*, Oct. 1927, reproduced here through the courtesy of my friend the Editor, Mr. W. D. Doolin); recent subglenoid luxations of the shoulder with fractures comminuting the proximal parts of humerus. In every case exposure was completely satisfactory; in none did the chip fail to unite with clavicle, and none has required removal of wire, thread or catgut.

I have often wondered, however, if a subperiosteal detachment of deltoid would be compatible with the sound function I got after cutting the chip. And I had the fortune to hear from the late Lt.-Col. H. A. Brittain, R.A.M.C., that excellent results will follow. More sutures must be used to tie the muscle back in place than when it swings out on a rod; but that is no objection.

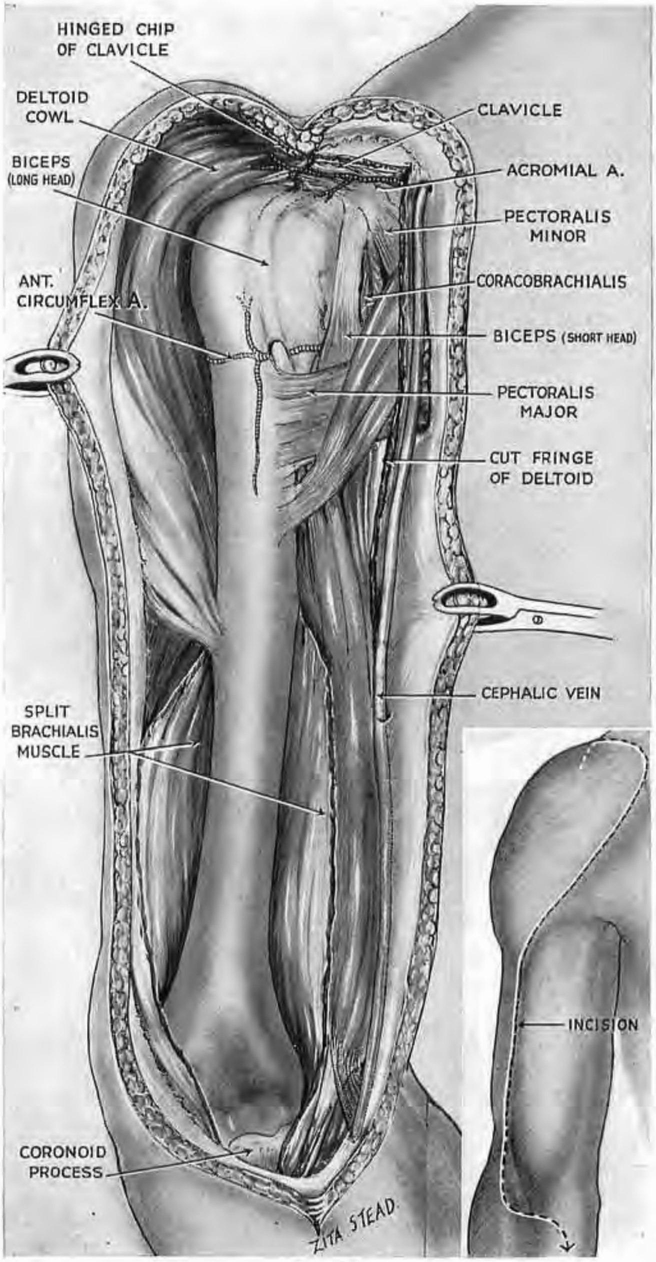


Fig. 24

Complete anterior exposure of the humerus, embracing shoulder and elbow joints, is obtained by combining the proximal and distal exposures in one procedure. The inset shows the full incision. The flexor crease at the elbow lies two fingerbreadths below the epicondylar level. The incision crosses just below the crease. Musculospiral does not appear unless we wish (see Fig. 23).

over it; the knife enters the flank a fingerbreadth lateral to the biceps edge and goes obliquely in to reach the front of the bone *at the middle line*—a vital emphasis (Fig. 22). (I have only once seen the nerve injured in scores of humeral exposures—then by a glancing, misdirected cut, wide of the ample target.) The outer strip of brachialis, thus separated, forms a buffer protecting the musculospiral (or radial) nerve from the rugine. The nerve is not seen if the front only of humeral shaft is exposed; the back, too, can be cleared safely while the nerve is concealed. But (should the surgeon wish) the musculospiral, in adults, is always found one fingerbreadth distal to the deltoid eminence by gentle blunt dissection through the buffering slip of brachialis (Fig. 23). Light pressure on this buffer removes the nerve sufficiently from contact with the shaft to give a rugine access. (This facultative finding of the nerve was plain in the original account (*loc. cit.*), but has been missed in later adaptations.)

The brachialis may be split to just within two fingerbreadths of the epicondyles without entering the elbow joint. Watch for sharp bleeding from a vein divided in the upper fibres. The bone, seen through the split, lies, in extension of the limb, deep and unworkable. Flexion of the elbow to a right angle transforms this appearance, relaxing the muscles and leaving the bone widely accessible in a shallow wound (Fig. 23).[1]

The elbow joint.—This joint can be opened—and even excised from in front—by a further splitting of brachialis. The tip of the coronoid process and the trochlea are at once visible; the capitulum and head of radius appear with adequate retraction.

After a distal approach, extension of the elbow before suturing the fascia will close of itself the wide wound in brachialis.

The whole front of humerus can be laid bare by combining the proximal and distal approach (Fig. 24); and we can, of course, expose any segment by using shorter lengths of the full-length incision. But these should not be short.

If, therefore, it is possible to reach objectives (sequestra are the commonest example) *without* hinging back the deltoid, we need not hinge it back,—a sentence one would like to think superfluous.

[1] For a continuation of distal exposure of humerus into antecubital fossa see p. 90.

EXPOSURE OF THE PROXIMAL PART OF HUMERUS COMBINED WITH AXILLO-CERVICAL EXTENSIONS TO NERVES AND VESSELS

Some score years ago with D. Bowie, F.R.C.S., then surgical specialist to Cairo Command, I saw a case of fracture-dislocation of the shoulder showing complete brachial palsy. We had thus to explore the bone, the joint and proximal parts of all the brachial nerves. The shoulder-strap incision described above (Fig. 18), combined with detachment of a clavicular chip (Fig. 19), served well; bone and joint were dealt with, and, after dividing the tendon of pectoralis major, each nerve was seen and fortunately found intact. The following account will give a sort of formula for multiple procedures of the kind.

AXILLARY EXTENSION OF THE PROXIMAL APPROACH TO HUMERUS.—The shoulder joint and upper part of humerus are first exposed (see p. 29). Then, when the deltoid is turned back, divide the tendon of pectoralis major close to its insertion and draw the muscle inwards (Fig. 25). The loose fascia now seen spreading between the divergent coracoid origins of pectoralis minor and coracobrachialis covers the main neurovascular bundle of the axilla. Open the fascia near the coracobrachial belly avoiding the musculocutaneous nerve which enters a medial *groove* on that muscle two fingerbreadths below the coracoid; farther down, the nerve tunnels through the muscle belly.[1]

When we have opened the loose axillary fascia it is quite easy to take the wrong path—even after careful warning—and be lured by the inviting space between bone and the composite band formed by short head of biceps plus coracobrachialis (Fig. 25). Resist that lure and keep dissection *medial* to the band. The nerves lie there in easily remembered grouping round the vessels (Fig. 25).

Some special points deserve a reference. The *median nerve* can as a rule be found, even with eyes shut, by Farabeuf's simple expedient—drawing the pulp of a finger across the main axillary bundle towards coracobrachialis; the nerve comes with the finger and leaves the artery bare (Fig. 25). The circumflex and musculo-

[1] Pictures in text-books of anatomy show the musculocutaneous dissected out of the coracobrachial groove; they therefore stress a relation of nerve to muscle which begins only at the *tunnel*. That, I think, is why we learn to expect the musculocutaneous in a third-stage axillary ligation, and why we seldom find it: the nerve has sunk into the groove and left the median to skirt the lateral edge of neurovascular bundle.

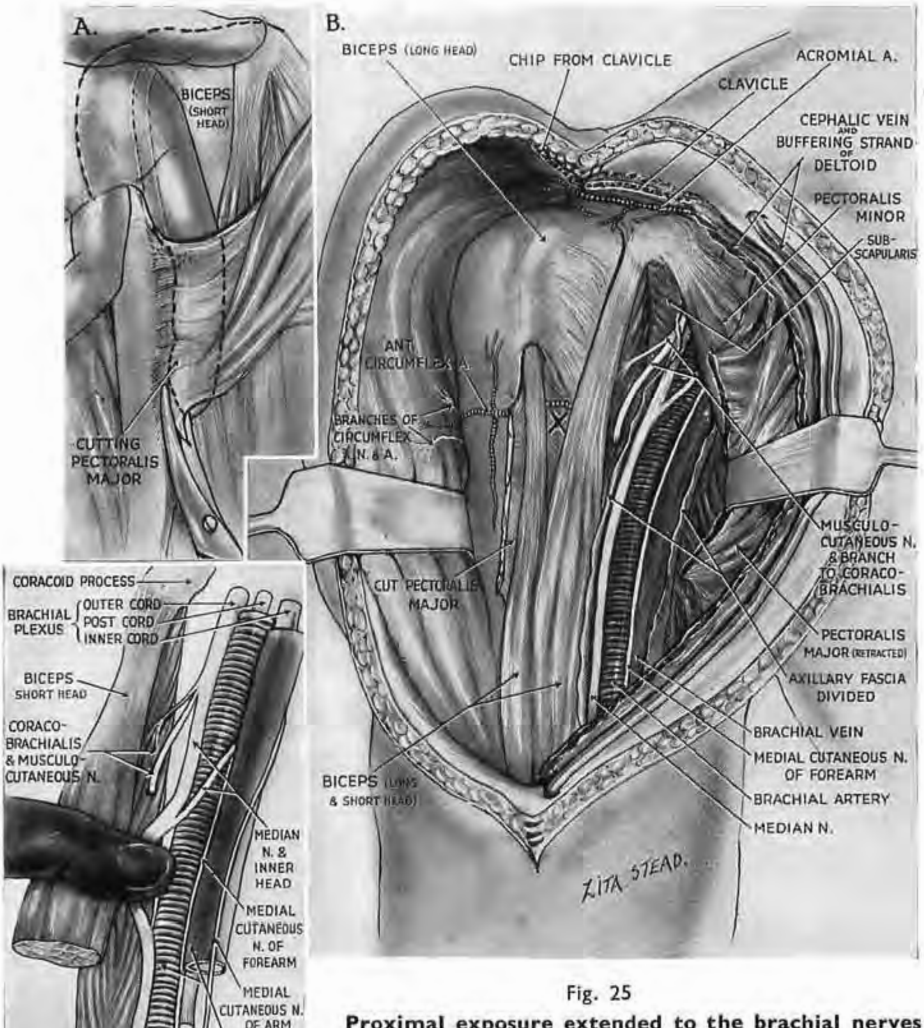


Fig. 25

Proximal exposure extended to the brachial nerves

A. The pectoralis major divided. B. The resulting exposure. X marks the pitfall to avoid when defining the neurovascular bundle—the tempting much-frequented interval between short head of biceps and humerus. (The bundle is, of course, *medial* to the common mass comprising biceps head and coracobrachialis.) C shows the relation of nerves to the double-barrelled lie of vein and artery in the axilla : the medial cutaneous nerve of forearm occupies the groove that demarcates the barrels in front ; the hinder groove conceals the ulnar nerve ; median overlies the outer border of the artery and is accompanied by musculo-cutaneous, while medial cutaneous of the *arm* is on the inner border of the vein. C also shows Farabeuf's ' blindfold ' method of locating the axillary part of median nerve.

spiral nerves spring from the hinder cord ; they thus lie deeper than the rest and come less easily to hand.

The circumflex nerve.—This nerve, considered for a surgical exposure, has here two parts—axillary and retrohumeral (Fig. 26).

The *axillary portion* which suffers most from injury lies deep ; and having failed on more than one occasion to find it quickly, I learnt at length to recognise it blindfold—defining in the first place with a finger the thick mass of main neurovascular bundle.

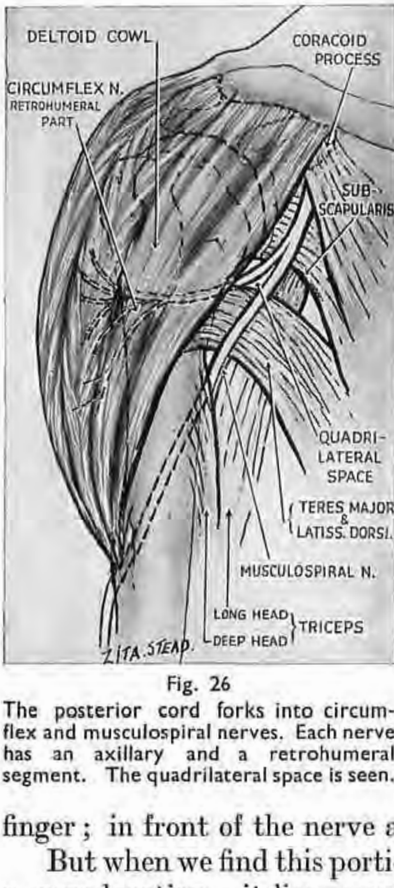


Fig. 26

The posterior cord forks into circumflex and musculospiral nerves. Each nerve has an axillary and a retrohumeral segment. The quadrilateral space is seen.

Location of the axillary part of circumflex by touch.—Stand behind the top of the patient's shoulder and use your right index for his left side, your left for his right. Place the tip of the finger on the tip of the coracoid ; aim into the angle formed by the divergence of pectoralis minor and coracobrachialis. Slide the finger obliquely—down, in and back—across the coracoid tip as far as the proximal interphalangeal joint. The tip of the finger penetrates soft areolar tissue above the level of the bundle, and, slanting down behind it, stops against the front of the subscapularis (Fig. 27). Now turn your index and hook the distal phalanx gently out towards the arm ; the thick strand thus caught by the pulp of the finger is the circumflex bundle : the nerve lies next the finger ; in front of the nerve are the posterior circumflex vessels.

But when we find this portion of the circumflex we have achieved a mere location : it lies as yet too deep, and seems too short, for useful intervention. Not till the clavicle is cut at the responsive point (p. 44), letting the limb fall outwards, will a workable length of nerve come near enough to the surface for convenience.

The *retrohumeral part of the circumflex* disappears through the quadrilateral space above the thumbwide band of latissimus and teres major tendons (Fig. 26). A finger easily enters the distal part of this space and follows the transverse course of the bundle round behind the humerus; it lies in a loose zone of cleavage between deltoid and surgical neck.

EXPOSURE OF THE RETROHUMERAL PART OF CIRCUMFLEX.—This portion of the nerve is only seen by further mobilising deltoid—first distally as far as the insertion; then at the proximal attachment.

Separation of the acromial origin of deltoid.—Leaving a strand to buffer the cephalic vein (pp. 27 and 31) the whole deltoid hood is mobilised without division of its fibres, first by detaching the hinged

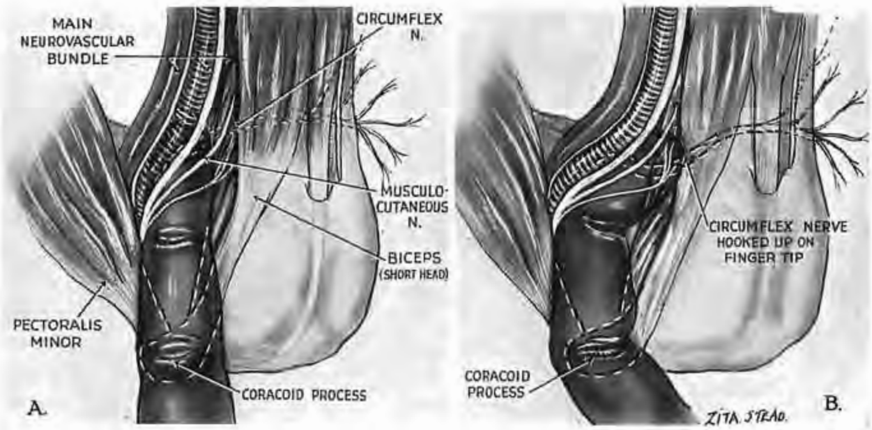


Fig. 27

Locating the axillary part of the circumflex nerve by touch

A. The index finger (the left for the right side—as in this figure—and *vice versa*) slides from above the patient's shoulder, on its palmar aspect, *across* the coracoid tip, *into* the angle between pectoralis minor and coracobrachialis, *behind* the main neurovascular bundle, viz. down, in and back. Stop the finger when its proximal interphalangeal joint covers the tip of coracoid. The distal phalanx has then reached subscapularis—the soft mass in front of scapula.

B. Now turn the finger out towards the arm. The distal phalanx hooks the nerve.

clavicular chip completely, and then by cutting off with a chisel the deltoid edge of acromion (Fig. 28). Adopt the stance employed for slicing off the deltoid chip (p. 32)—' below ' the patient's right shoulder; ' above ' his left. And once it bites into the bone, seat the chisel on its bevel (as in Fig. 19) and take the merest shaving from acromion, *except* at the acromial angle. Cut this angle off obliquely in such a way that when replaced it will fit firmly on the scapula. The whole bony margin—acromial plus clavicular—looks like a bent and sprawling U with one limb broken (Fig. 28, c). This separation is by no means difficult, but does demand most careful study of skeletal contour (Fig. 28) and gentle guidance of a *sharp* chisel. The very wide exposure thus obtained (Fig. 29) should also find a use in the rare case where mere *clavicular* detachment gives insufficient access to the shoulder, and where as well we have the chance of saving deltoid function.

The final restoration is extremely simple, for to secure it we need only tie back into place the chip first cut from clavicle. A single ligature will thus reconstitute the origin of deltoid—in front, behind and at the side.

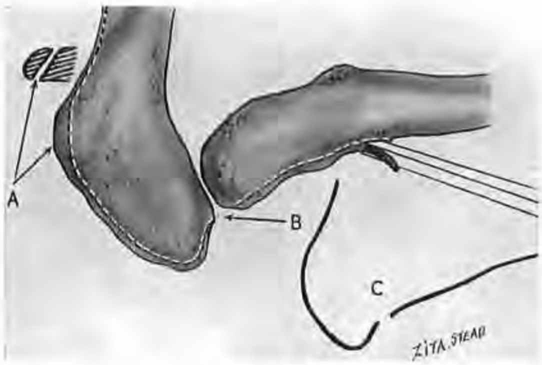


Fig. 28

Separation of the deltoid origin extended to acromion

A. The acromial angle ; the broken line marks the direction of the cut seen from above. The sagittal section shows in diagram the *slope* of the cut which lets the separated angle fit back later like a cap. B. The 'difficult' corner between the bones—where it is easy to drive the chisel *through* acromion instead of round its edge. C. The outline of the cut seen from above—a sprawling U with one limb broken. (The chips from clavicle and acromion are linked across the joint by ligament so that a single suture round the clavicle reconstitutes the deltoid origin.)

The musculospiral nerve.—The musculospiral runs obliquely in front of a useful landmark, the composite teres-latissimus tendon which crosses the field four fingerbreadths below the coracoid tip. The nerve lies, remember, like the circumflex, *behind* the main neurovascular bundle, shut off from it and bound by thin transparent fascia, so that when we draw the bundle inwards the musculospiral is often left unmoved and visible (Fig. 30).

The vascular tether.—But first we may have to sever a short leash of vessels that ties the bundle to the coracobrachial belly, near the latissimus tendon. A finger travelling down the belly catches the leash which comes either from brachial or profunda vessels ; and since the leash is short these last are easily hooked

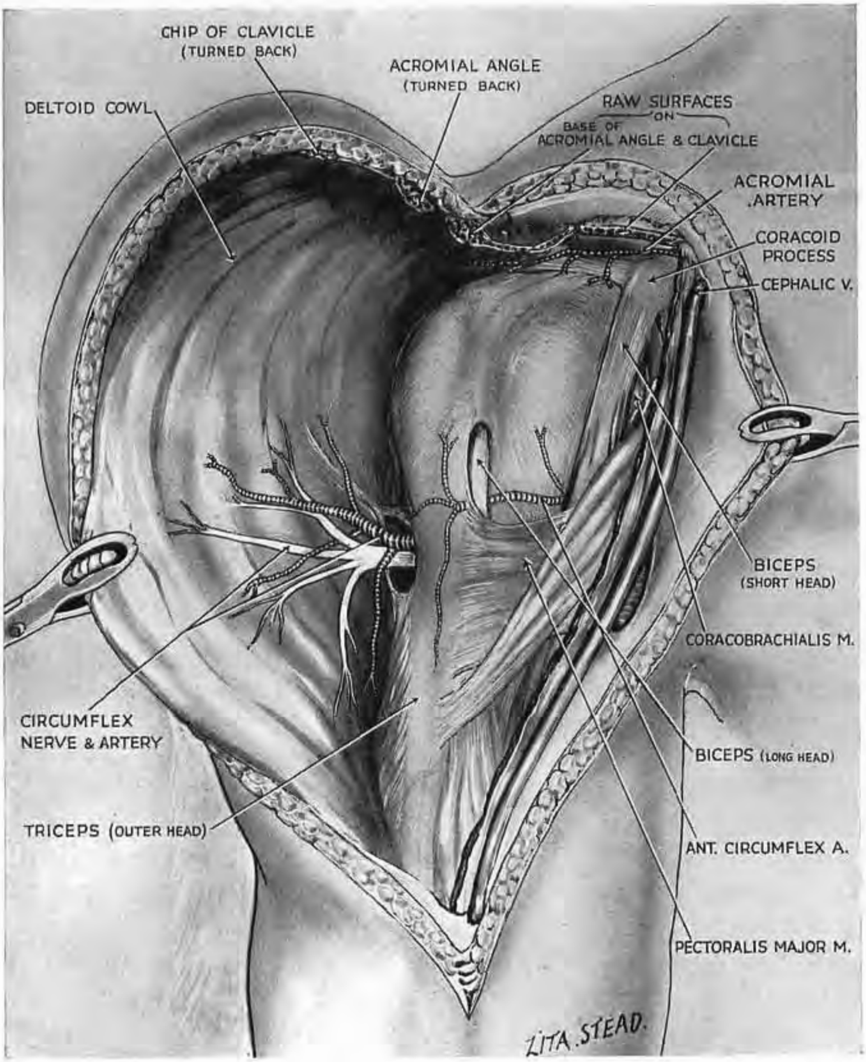


Fig. 29

Subtotal detachment of deltoid

Exposure of the retrohumeral part of circumflex obtained by detachment of the clavicular *plus* the acromial origins of deltoid. The wide, incidental, view of shoulder joint—front, side, and back—suggests further use for this subtotal deltoid separation. *One* ligature (placed as in Fig. 19, C) restores and clamps both origins.

up with it (Fig. 30). We shall do well, therefore, to separate and view the structures caught by the finger before dividing the leash, sparing of course the large profunda.

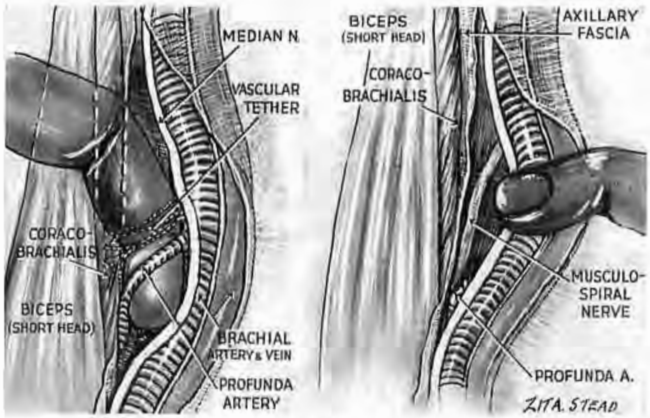


Fig. 30

A vascular tether binding the main bundle to coracobrachialis may need division before the bundle can be drawn aside to expose the musculospiral nerve. A finger hooked down the medial face of coracobrachialis picks up the tether—and sometimes the large profunda vessels with it. So look before you cut, and spare profunda.

THE CORDS OF BRACHIAL PLEXUS.—The cords from which the nerves arise are thoroughly exposed if the narrow, coracoid end of pectoralis minor is cut across.

EXTENDING THE EXPOSURE FROM THE AXILLA TO THE NECK.—For this the clavicle must be divided. The site made use of by Fiolle and Delmas affords a real seat of election, three fingerbreadths lateral to the sternal end (Fig. 31, Part 1). Division of the bone too far in threatens the subclavian vein which lies so dangerously close to the medial inch of clavicle; on the other hand, a section too far out leaves an inner piece of shaft whose overlap conceals our main objectives. The 'seat of election' corresponds in general to the outermost edge of the sternomastoid origin—a place to remember; for there the external jugular vein penetrates deep fascia; there, on a deeper level, we shall find the outer edge of scalenus anterior underlying that of sternomastoid—the two as if about to coincide in Euclid's mind.

When the clavicle is sectioned we can use the weight of the limb—some 7 or 8 pounds in the adult—to lever the outer fragment from in front of the plexus.

Position and incision.—The field is opened by turning the

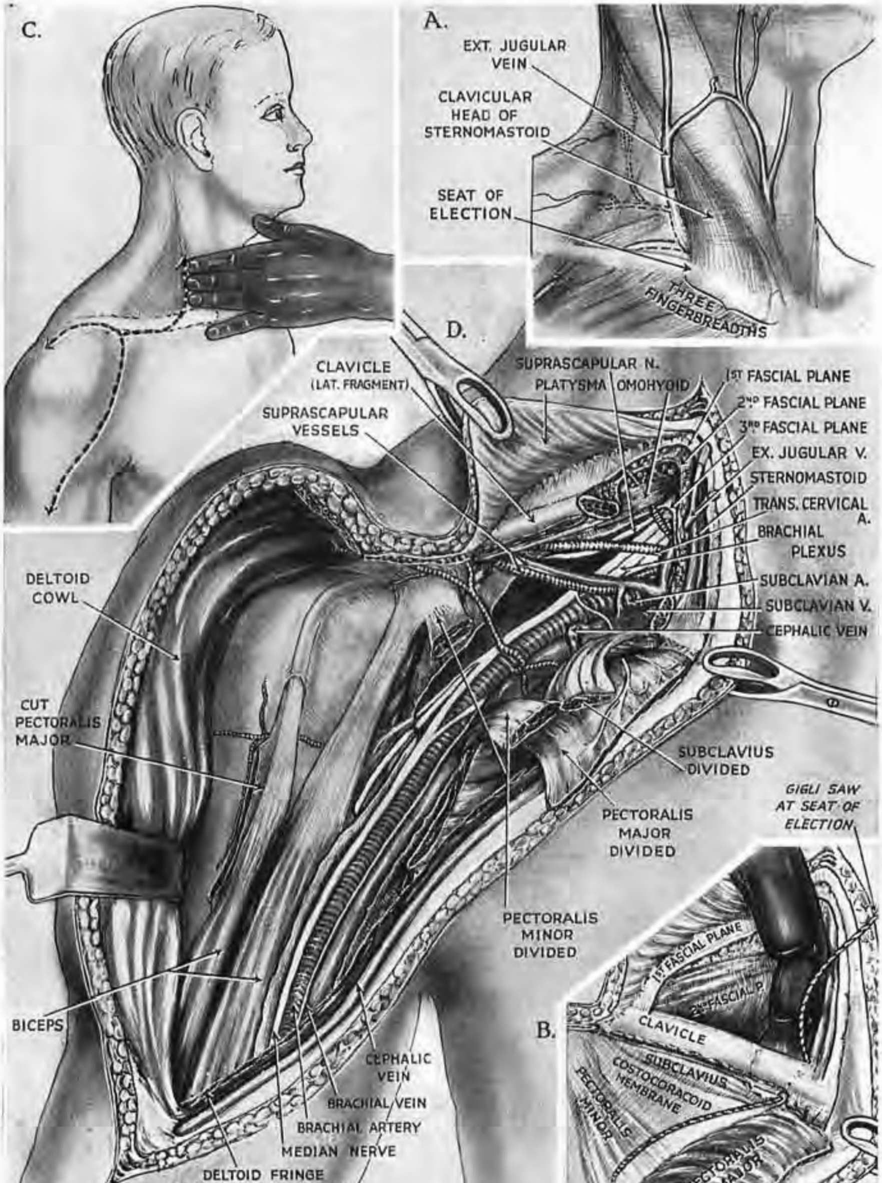


Fig. 31, Part 1

Exposure of nerves and vessels continued from axilla into neck by cutting through the clavicle

A and B. Seat of election for dividing clavicle, three fingerbreadths from the sternal end. It borders generally on the outer edge of sternomastoid—an edge which if displaced directly back would ' coincide ' with that of scalenus. Note the relation of external jugular.

C. Incision for *unforeseen* extension from joint and axilla to neck, going in from the ' strap ' to a fingerbreadth beyond the ' seat ', and then up sternomastoid—a useful makeshift (*cf.* Fig. 31, Part 2).

D. The view after (1) dividing pectoralis major close to clavicle ; (2) dividing pectoralis minor ; (3) dividing clavicle itself ; (4) drawing the limb clear of the table so that its *weight* will swing aside the outer fragment. This last manœuvre levers up the final tether (belly of subclavius). Cut through it, taking care to guard the sometimes formidable suprascapulars.

patient's head and neck away, and pulling on the hand to bring his shoulder down. Then comes the question of incision. Supposing, for example, we have used a 'shoulder-strap' and bared the joint, only to find that we must *add* an exploration of the root of neck,

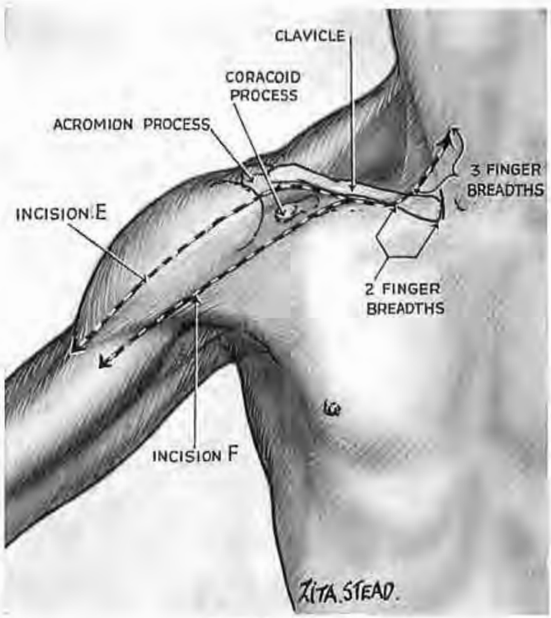


Fig. 31, Part 2

Skin incision for planned axillo-cervical approach

E. *For exposing axilla plus shoulder joint plus root of neck,* abduct the arm to straighten your cut. Divide skin lengthwise over deltoid, aiming a thumbwidth *lateral* to the tip of coracoid. Curve the cut in along the lower edge of clavicle, and up, two fingerbreadths from sternum.
F. *For simple axillo-cervical approach* again abduct the arm. By-pass the joint with an incision curved like E, but aimed a thumbwidth *medial* to coracoid.
Incision E affords inclusive access to the joint (Fig. 19). Incision E or F leaves room for opening the pectoralis lid to the axilla; then for dividing moorings of the clavicle—a barrier which, cut across, not only swings aside but lets the shoulder girdle turn and offer up the contents of axilla on the scapula, as on a plate.

the requisite incision goes inward from the 'strap'—a second-best though workable procedure (Fig. 31, Part 1). But if we *plan* combined exposure—whether of shoulder joint and neck with axilla, or merely of axilla with neck—then we shall make a single cut, placing it farther in or out, to let us by-pass or include the joint (Fig. 31, Part 2). Reflect skin sufficiently to show three things: the site for dividing clavicle; the origin of pectoralis major lateral to that site; the lower fourth of sternomastoid.

Add—to expose the shoulder joint—the outer third of clavicle.

Division of pectoralis major and clavicle.—After severing the muscle near its humeral attachment we must divide it from the clavicle as far inwards as the place for bone section, so that presently the lateral fragment (which blocks our view of nerves and vessels) lies ready to be swung aside.

We now turn to the neck and open the most superficial of the three layers of deep cervical fascia close to this 'seat of election.' A finger introduced from above completes the isolation of the clavicle at the right spot. The instrument of choice for dividing the bone is a Gigli saw.[1]

Then, if we bring the limb well over the edge of the table, its weight will lever up the outer piece of clavicle and stretch the belly of subclavius. This we must divide without dividing vessels—variously termed the transverse scapular [2] or suprascapular—whose long *retroclavicular* course (stressed by the Baron Boyer in Napoleon's time) runs close behind subclavius. Many to-day, I notice, find their site and magnitude surprising. But John Bell, who lived his anatomy, often saw the artery (which frequently springs from the third stage of subclavian) "large, very long, tortuous like the splenic artery, and almost equalling it in size" (Fig. 31, D, Part 1). The vein may bulk still larger.

Section of the clavicle allows rotation of the scapula, which brings structures of axilla *forwards*, and, notably, the deep-seated circumflex nerve.

Before proceeding to the neck let us improve acquaintance with the *layers* of cervical fascia and (like an expert "digging up the past") enlist their help as guides.

THE DEEP FASCIAL PLANES ABOVE THE CLAVICLE

Three are found here. The first is an *investing layer* which gives a sheath to trapezius and sternomastoid, and cloaks the

[1] By this I do not mean the futile things, of late in regular supply, which cut slowly and broke quickly—even with careful punctilio in the matter of angulation. I mean the tough Gigli saws (chosen with characteristic flair) that form part of the neurosurgeon's armoury. They cost a trifle more; they cut fast, and for two years I watched class after class bend them double and pass them on intact.

[2] 'Transverse scapular' (B.N.A.): a factitious, 'portmanteau' title caught from the well-named transverse cervical vessels that lie contiguously. 'Transverse' they certainly are—in the neck; 'scapular,' certainly in destination. But certainly not 'transverse scapular': they have a lengthwise course along the bone.

intervening triangle. Deep to this layer is a mass of fat and glands mingled with terminal twigs of transverse cervical and suprascapular vessels.

Next comes a loose, *intermediate layer* of deep fascia which loops round the posterior belly of omohyoid and, like a mesentery,

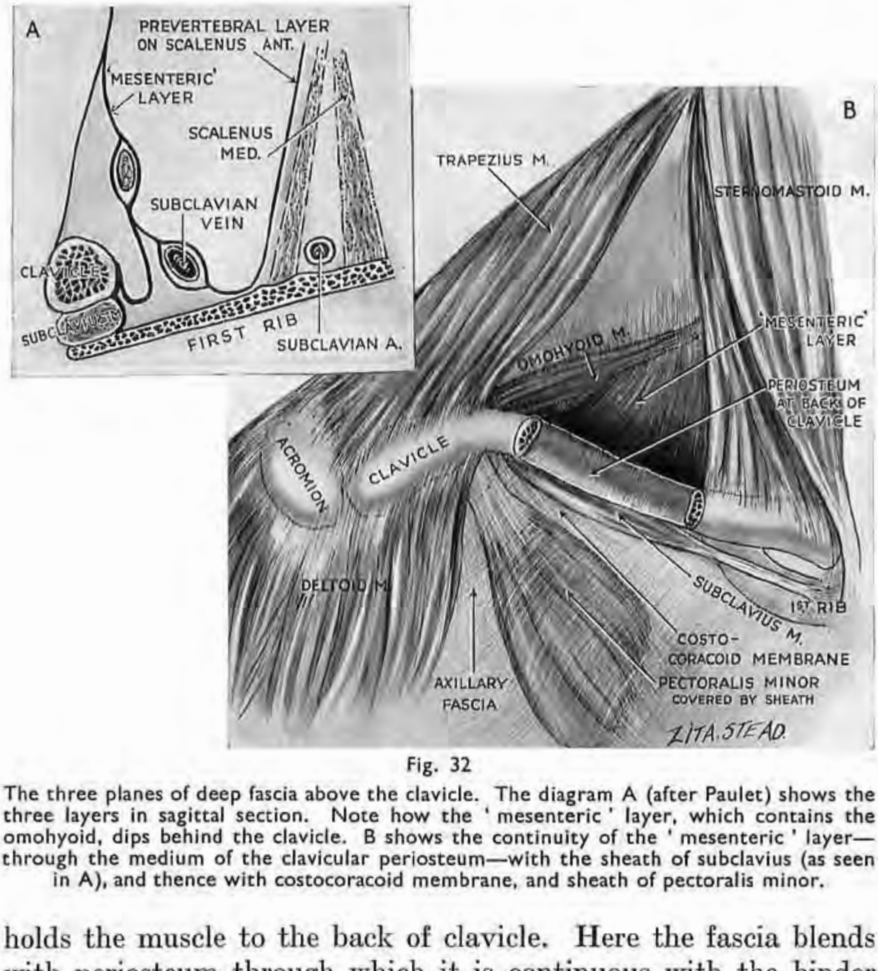


Fig. 32

The three planes of deep fascia above the clavicle. The diagram A (after Paulet) shows the three layers in sagittal section. Note how the ' mesenteric ' layer, which contains the omohyoid, dips behind the clavicle. B shows the continuity of the ' mesenteric ' layer—through the medium of the clavicular periosteum—with the sheath of subclavius (as seen in A), and thence with costocoracoid membrane, and sheath of pectoralis minor.

holds the muscle to the back of clavicle. Here the fascia blends with periosteum through which it is continuous with the hinder layer of subclavius sheath, and that descends towards the chest to form the costocoracoid (or clavipectoral) membrane which gives a covering to pectoralis minor (Fig. 32).[1]

It will thus be clear that when we divide the clavicle we open

[1] My appreciation of a fibrous sheet spreading (beyond both) from omohyoid to pectoralis minor, and crossed but not broken by the adhering clavicle, is due to an admirable specimen made by my friend Major E. E. Dunlop, D.A.D.M.S., Royal Australian Army Medical Corps.

this second, 'mesenteric' layer—unless, of course, we first shell the bone out of its periosteum. The omohyoid belly may lie far down, behind the clavicle, or rise some fingerbreadths above it on a long 'mesentery'; it is a guide of great worth—a bathymetric muscle that measures the *depth* we have attained—and (like the posterior belly of digastric) flags the subjacent presence of all the neurovascular structures of chief account in its own part of the neck. Deep to the 'mesenteric' layer is a second complex of fat and glands, containing this time the main trunks of the transverse cervical and suprascapular vessels.

The third and last layer of deep fascia is the *prevertebral*; it spreads like a tight sheath of dull cellophane over the front of the scalene mass, binding on to these muscles the mesh of brachial plexus, the subclavian artery, and the phrenic nerve. (The nerve may travel *in* the fascial layer.) Deep to this layer there is *no* mass of fat and glands.[1] (It will be noticed that mention has not been made of the subclavian vein which lies sunk in this region, divorced from its artery by scalenus anterior. It is closely bound to the innermost part of the clavicle but is far enough away at the point of section to be avoided easily by hugging the bone.)

THE CERVICAL EXPOSURE RESUMED.—With these facts grasped we may proceed in all confidence, recognising and dealing with each stratum in turn—the three fascial layers; the two fatty screens. We shall divulse the fat and spare the vascular twigs by means of Mayo scissors, opening the fascial layers with the same respect we have for peritoneum, or—in the case of the last layer, the prevertebral—for dura mater; and with no less assurance. (The belly of the omohyoid may be severed or drawn aside, as is convenient.)

THE MEDIAL EXTENSION THROUGH STERNOMASTOID.—Should we wish to carry our exposure in across the neck, we must divide the clavicular head of sternomastoid—an act that calls for circumspection: the internal jugular vein is often fixed in fat to the deep face of the muscle. Old periadenitis—as over the carotid fork—may felt the structures too closely for 'blunt' separation, making it

[1] *Deep juxtaclavicular fascial layers of neck.*—These three may be remembered as layers in a club sandwich arranged thus: (1) *investing layer of deep fascia*; (2) complex of fat, glands, and terminal twigs of transverse cervical and suprascapular vessels; (3) *intermediate* ('*mesenteric*') *layer of deep fascia* enclosing the posterior belly of omohyoid; (4) complex of fat, glands, main branches and tributaries of transverse cervical and suprascapular vessels; (5) *prevertebral* ('*cellophane*') *layer of deep fascia*. (This last is really a lateral, *prescalenic* extension of the true prevertebral fascia. The true prevertebral fascia clothes longus capitis and longus colli.)

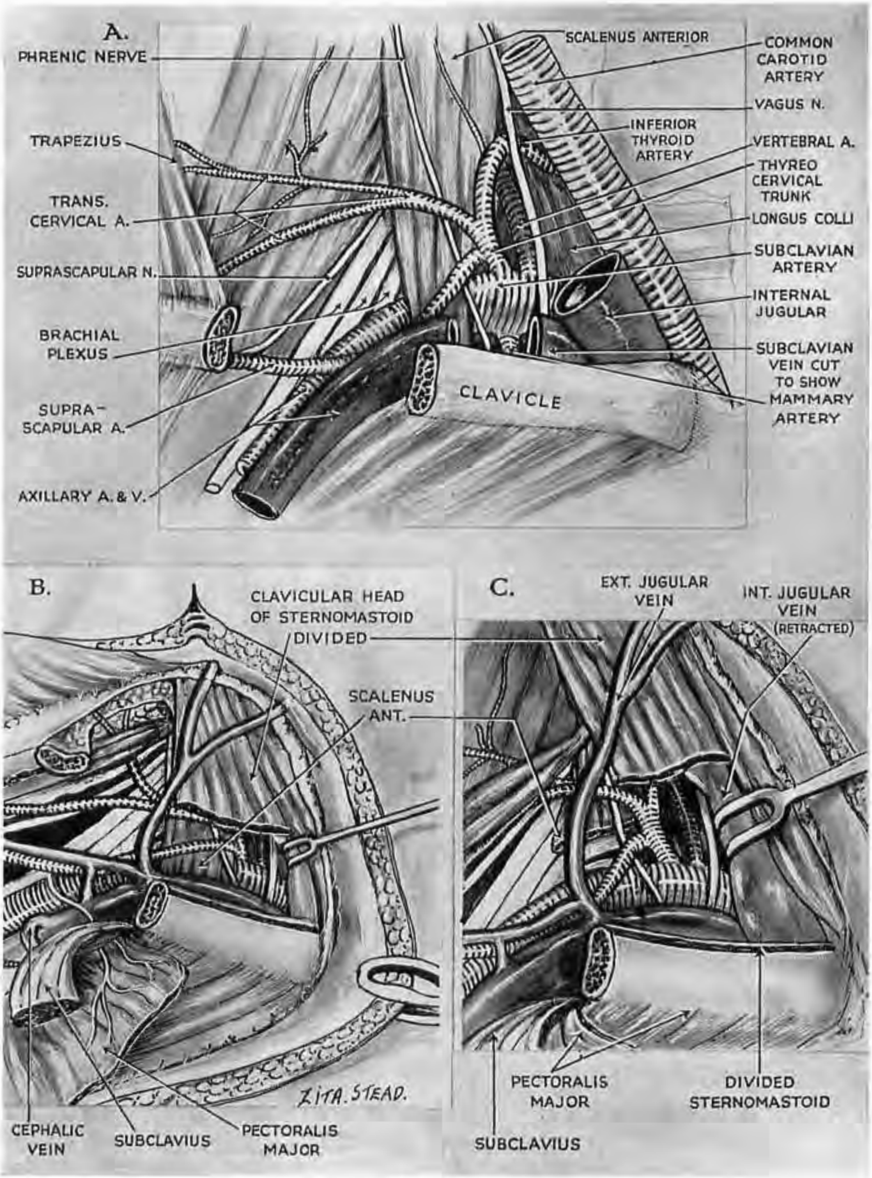


Fig. 33

The axillo-cervical exposure extended medially

The upper figure, A, is to remind us of anatomy. Sternomastoid has been entirely removed. B. Divide the clavicular head of sternomastoid *surgically* (see text), respecting external and internal jugular veins ; scalenus comes to view. Isolate scalenus *as you would an artery*, releasing phrenic nerve and vessels crossing it. C. Divide scalenus near the first rib. Note that its costal end withdraws and lets the two subclavian trunks touch in their second stage. Note how the lowest trunk of brachial plexus is ensconced between scalenus medius and subclavian artery. The posterior belly of omohyoid is not labelled in B and C. In B it is partly hidden by the distal piece of clavicle whose cut face shows how the weight of the limb has rotated the shoulder girdle.

(Clavicle, as a rule, hides the subclavian vein ; here the vein is high.)

most dangerous to slide a finger under and pick up this head of sternomastoid for mass division. It is wiser, therefore (after dividing the 'safe' lateral fingerbreadth), to cut gradually through the front of the head, and use a finger to displace the deepest fibres from the vein.

Occasion may be found for a further safeguard, using the suprasternal space of Burns and Grüber's diverticulum.

BURNS' SPACE AND ITS DIVERTICULA.—Two accounts of this space are currently accepted. Merkel's, which prevails in our own text-books,[1] supposes a suprasternal cleavage of the investing layer of deep cervical fascia—an arrangement which, if actual, would offer no surgical advantage.

The second and fruitful view is favoured by French anatomists, though for reasons that seem less cogent than the little-finger test I shall describe. The French regard the space as an enclosure whose boundaries are formed by adhesions occurring between two fascial layers at the cavity's *margin*—the investing layer (1) uniting there with (2) the intermediate or 'mesenteric' (p. 48). From this central space of Burns a short *cul-de-sac*, the diverticulum of Grüber, projects transversely on either side, extending for about an inch along and behind the upper face of clavicle.

If the first or 'cleavage' view of Burns' space were correct, we should expect the fascia forming a Grüber's diverticulum to behave like investing fascia, in which event it would ensheathe the lower end of sternomastoid. *It does not do so*—the diverticulum lies in a plane *behind* the sternal foot of the muscle, and may even reach out behind the foot of its clavicular attachment.

According to the second or 'adhesion' view the back wall of Burns' space, and so of Grüber's diverticulum, is formed by the *second* layer of deep cervical fascia—the intermediate or 'mesenteric' layer which is the special sheath of infrahyoid muscles (Figs. 34 and 37). When, therefore, we open the central space of Burns, the little finger passed into it and out along a Grüber's diverticulum will, first, occupy the short diverticular lumen and there lie sandwiched between the sternal foot of sternomastoid in front and the infrahyoid 'strap' muscles posteriorly. Then, guided by the lumen, the finger can break gently onward through the blind end of the *cul-de-sac* and slide past the clavicular foot of sternomastoid. Moving close behind this foot

[1] T. H. Bryce, however, supports the second view (Quain's *Elements of Anatomy. Myology*, 1923, p. 64).

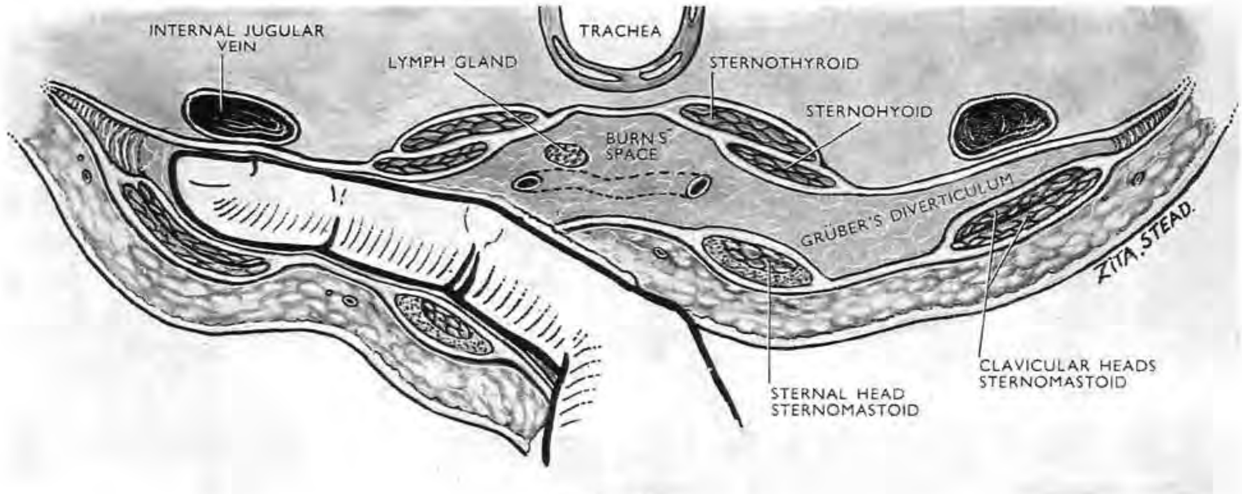


Fig. 34

A finger passed from the central space of Burns along or beyond the diverticulum of Grüber has in front of it the sternomastoid ; behind it, the sternohyoid and sternothyroid muscles. The finger-tip separates the clavicular part of sternomastoid from the internal jugular vein, making an excellent safeguard when the muscle is divided. (The junction between the two anterior jugular veins lying in the central space of Burns is not labelled.)

Note how the intermediate (mesenteric) layer of deep cervical fascia—which ensheathes the strap muscles (Fig. 37)—forms the back wall of Burns' space.

it opens a safe path in front of the internal jugular vein, and in front, too, of any fringe of infrahyoid belly that may spread to cover the vessel. For this reason the diverticulum of Burns' space can be used as a safeguard when dividing the clavicular foot of sternomastoid. And let no one scorn its aid: help of this kind is by no means superfluous; I have twice seen an internal jugular vein severed along with the covering muscle by a single cut—magnificent commando work but not surgery.

The transverse part of the anterior jugular vein which may occupy Grüber's diverticulum is easily spared.

The subclavian artery in continuity.—Section of the clavicular head of sternomastoid gives a good view of scalenus anterior with a glimpse of phrenic nerve (still under its cellophane fascia) sloping down and in across the muscle. Then, if we first free the nerve and its small companion vessels, we can isolate the scalene muscle as we should isolate a great longitudinal artery; and after cutting through the belly close above the rib all three stages of subclavian trunk are seen in continuity (Fig. 33, c). Most of the branches, too, are visible, or can be brought to light by gentle blunt dissection. The vertebral artery with the vein in front of it disappears up into the apex of the deep angular space between the divided scalene muscle and the longus colli clothing the vertebral column. (Fig. 33, A, shows the origins of subclavian branches. Note the thyrocervical trunk rising and branching beside the inner scalene edge, directly opposite internal mammary.)

EXPOSURE OF CERVICAL STRUCTURES BY STERNOMASTOID EVERSION

If Fiolle and Delmas had done nothing else for surgical exposure, their short supplemental cut which turns the ordinary straight incision along the front edge of sternomastoid into a 'hockey-stick' entitles them to fame. This supplement crosses and cuts down on the root of the mastoid process (Figs. 35 and 41) and so allows us to detach and evert the upper irretractile part of sternomastoid.

There was one flaw in this jewel: its authors advised a separation of the mastoid tip in order to mobilise the muscular attachment. But the attachment of sternomastoid climbs much too high on the mastoid process to be separated by cutting through the tip; it is also difficult to divide the bone cleanly, and the chisel is liable to smash a cellular process and leave it oozing. Mastoid

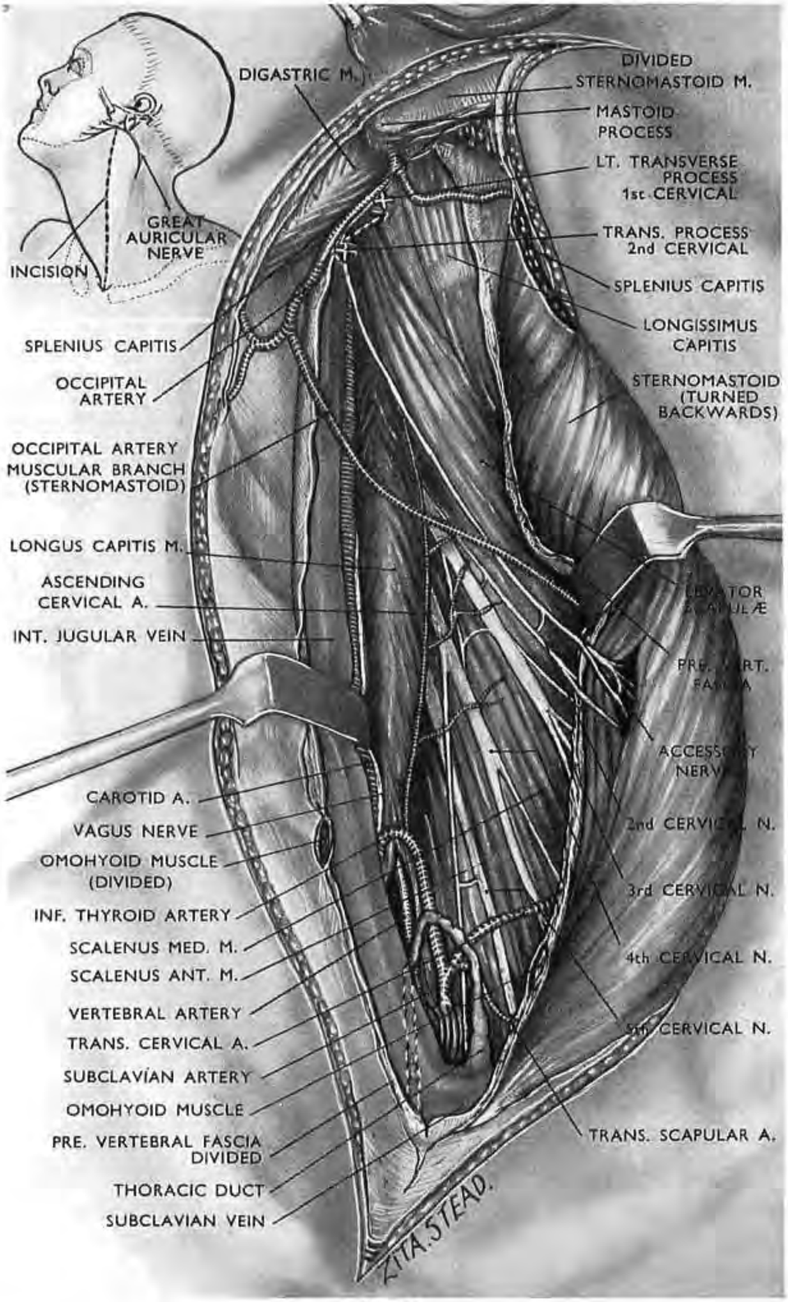


Fig. 35

The cervical part of the exposure got by sternomastoid eversion. (A) Accessory and second cervical nerves enter an interval between superficial and deep parts of sternomastoid (see Fig. 53).

At the root of neck the two arched structures of the left side are seen—thoracic duct and inferior thyroid artery ; also the vertebral artery, forming the shaft of the broad arrow made by longus colli medially and scalenus anterior laterally. The inset shows how the great auricular nerve is jeopardised (see footnote, p. 56, for McCollum's observation).

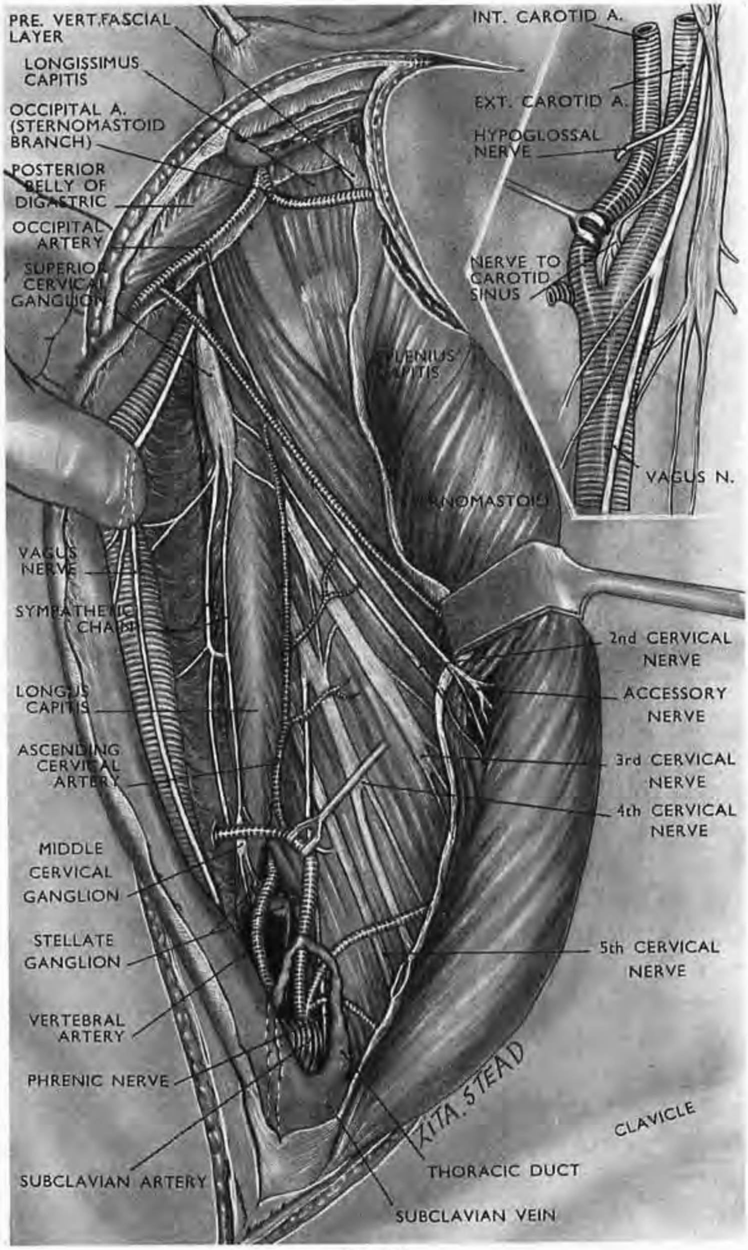


Fig. 36

The cervical part of the exposure got by sternomastoid eversion. (B) The carotid bundle is displaced medially showing the sympathetic trunk in the neck. A glimpse of the stellate ganglion is seen behind the vertebral artery. The inset shows vagal and sympathetic twigs to carotid sinus. The internal carotid artery hides the essential glossopharyngeal branch. (The last $\frac{1}{4}$ inch of the thoracic duct often looks blue because of venous reflux.)

section, in fact, is not only unlovely but useless. On the other hand, when the borders of the skin incision on the mastoid are reflected nothing is easier than to peel off the fibres of sternomastoid together with those of splenius.

When this detachment is accomplished and the upper part of sternomastoid has been everted well beyond a right angle, a superb approach begins to open, not only for the surgeon but for students of anatomy, giving to both at a most trivial cost in structure the freedom of the neck.

The special interest of Fiolle and Delmas lay, however, in the carotid bundle; but when there is need for further exposure we must secure a much more complete eversion of sternomastoid than they required for their limited objective. The skin incision continues down along the anterior edge of sternomastoid to reach the sternum. Then after dividing the investing layer of deep fascia together with two cutaneous nerves (anterior cervical and great auricular [1]), plus the transverse part of the anterior jugular vein, a single obstacle remains to stop eversion of the whole muscle and prevent displacement inward of the carotid bundle.

The omohyoid check.—Opposite the sixth cervical vertebra the omohyoid crosses deep to the sternomastoid sheath and superficial to the internal jugular vein which overlaps the carotid trunk. The tendon of the muscle is fastened to the deep face of the sheath, which here unites with the 'mesenteric' layer of deep cervical fascia—a fascia that wraps the omohyoid as though it were gut and moors it loosely to the clavicle (p. 48 and Fig. 32). This 'mesenteric' layer also clothes and links the bellies of the other muscles of the infrahyoid group, and with them represents in man and other mammals the single fleshy layer in the seal and certain reptiles (Fig. 37). The 'mesenteric' fascial layer is thus what French anatomists have called *une aponévrose déshabitée*, a forsaken muscle sheath. It shows at birth a trace of fleshy fibre and may retain through life a few striped shreds that cling like creeper to the internal jugular vein. The jugulo-omohyoid lymph gland, too, lying where the muscle crosses the vein, can become a focus of infective induration stemming from an ulcer at the tongue's tip, or spreading from nearby glands. Care is thus required when we free and divide this omohyoid check. With

[1] Mr. S. McCollum, Surgeon to the Adelaide Hospital, Dublin, tells me that his *men* patients who shave complain of the anæsthetic area produced in front of the angle of the mandible by section of the great auricular nerve. It should not be impossible (in the absence of dense adhesions) to save the nerve and free it far enough to leave sternomastoid 'on the leash' but mobile.

that done we can evert the *whole* sternomastoid through roughly two right angles ; then we can reach and deal with every structure of surgical importance in the neck (Figs. 35 and 36). A catalogue

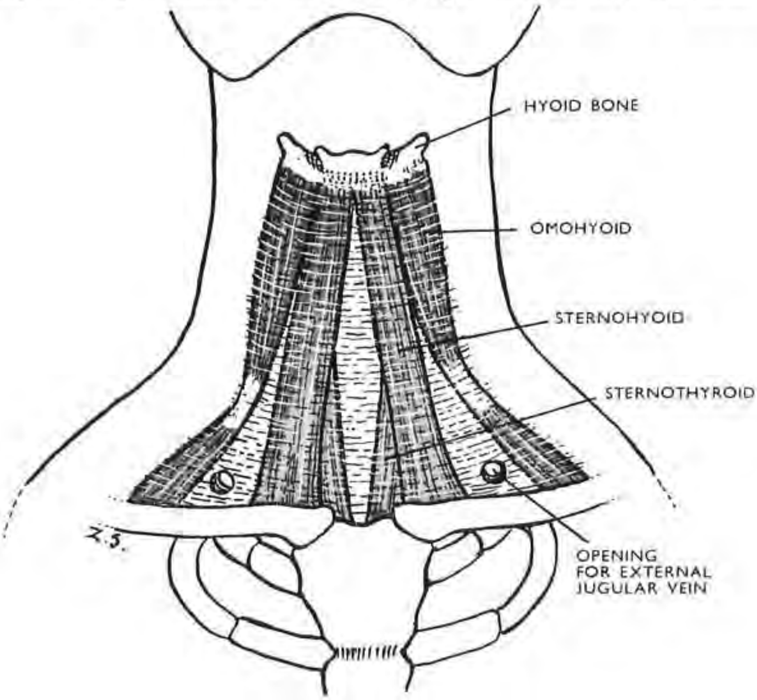


Fig. 37

The infrahyoid ' strap ' muscles ensheathed by the second (or ' mesenteric ') layer of deep cervical fascia. These muscles form a continuous layer in the seal, and in Uromastix, the spiny-tailed lizard of Egyptian deserts. In man there are gaps where the fascia is no longer occupied by muscle, forming the *aponévrose déshabitée* of French anatomists who agree that it is *this* fascia which forms the back wall of Burns' space (see Fig. 34). T. H. Bryce (Quain's *Anatomy*, 11th Edn., vol. IV, p. 64) also holds the French view against the consensus of British opinion which relates the space to cleavage of the first, or peripheral, layer of deep cervical fascia.

of possible objectives would therefore be as tedious as the recital of an index, and I shall merely name and deal with two :—

1. The vertebral artery in two parts of its second stage, and in its first.

2. The posterior rami of C1, C2, C3, C4.

The vertebral artery followed down on either side will lead us past the stellate ganglion, behind and past the arch of the thoracic duct on the left side. Down beyond this in the absence of adhesive lesions dissection with the finger can—without tearing a venule—expose the whole length of the left subclavian artery to where it springs from the aorta, or, on the right side the tight twisted fork of the innominate artery ; then the trunk itself, and with it part of the aortic arch.

THE VERTEBRAL ARTERY

EXPOSURE OF THE TOP SEGMENT OF THE SECOND STAGE [1]

This stage begins as a rule at the foramen in the sixth cervical transverse process and ends as the vessel leaves the upper rim of the foramen in the atlas vertebra (Fig. 38). *I* begin topsy-turvilly by dealing first with the all-but-final part of the *second* stage of this artery : its 'seat of election,' gauged by ease of access, lies at the top of the neck, near where the upper end of sternomastoid can be detached and everted from the mastoid process.

During the lapse of twenty years this method existed only as a glass-jar specimen at the Dublin Royal College, and as pages in a book—a cure, in fact, for which there was no disease. But there is a saying, older much than Homer (who quotes it twice), that new, valid material " will *of itself* lure and exploit its man." [2] And, after twenty years, the exposure was most courteously

[1] The substance of the following pages was written over thirty years ago and was later published in *Exposures of Long Bones and Other Surgical Methods*, Wright, 1927. On receiving my copy of the *Journal of Bone and Joint Surgery* for February 1956 I learnt for the first time (from a paper by Jefferson *et al.*, p. 114) that Drüner (1917) in *Zentralblatt für Chirurgie*, **44**, 67, had published a method of tying this same second-stage segment of the vertebral artery, which Sir Geoffrey agrees to regard as ' the site of election.'

The comment, however, that " Henry's operation is not strikingly different from Drüner's " would certainly have weight if the *objective* and not the approach is to be the test of an exposure ; then all exposures would be alike—whether the femur, for example were reached from the front, the side, or the back.

In the present circumstance (unless my German fails me), Drüner incises from the mastoid process downwards at the hinder edge of sternomastoid—" abwärts zum Hinterrande des Kopfdrehers (St. cl. m.) "—thereby threatening, rather than avoiding (as he claims), injury to the accessory nerve. Happily for me the wiser hands and heads of Fiolle and Delmas were there to lead my own approach down to the *front* of sternomastoid.

The whole drift of Drüner's access is different—use, for example, of a lesser occipital nerve as guide to the artery, instead of a plain trust in bony points. Indeed, I might make quite a list of variants if I could for a moment forget the heart-felt "Ha-ow pahltry ! " of a bored Yankee.

Applicability is, after all, what matters in a method ; and perhaps it is unreasonable to think that the rumour of virtual identity, with so august a background and so long a start, can be overtaken by fact.

[2] *Odyssey*, XVI, 294, and XIX, 13. In pre-Homeric days the new thing was iron—iron in the Bronze Age.

acknowledged and recurringly employed by Dr D. C. Elkin, then a colonel in the U.S. Army Medical Service (*Annals of Surgery*, 1946, **124,** 934). Nearer home, Mr Harvey Jackson, F.R.C.S., tells me he has used it on four occasions.

Prior to 1925, ligations of the vertebral, other than in the first stage, had been performed where the artery lies in its third stage upon the atlas arch. Even in the cadaver the passage of a needle round this atlantal portion of the vessel tears the large venous plexus which envelops it; and, whatever method of exposure is used, the vessel remains deeply placed in a limited field.

Injury to the venous plexus, with serious loss of blood, occurred in the two cases in which ligation of the third stage has been recorded,[1] and it seemed desirable to describe a simple *overt* method of tying the second stage of the artery, particularly as forcible hæmorrhage from the cephalic end of the vessel has occurred in cases where the vertebral was injured.

Actually, the question of tying this part of the vertebral arose in relation to a case of large innominate aneurysm which the late Sir F. Conway Dwyer was treating in 1925 at the Richmond Hospital, Dublin. His initial ligation of the right subclavian and carotid stems had resulted in a slight immediate diminution of the aneurysmal swelling, too small, however, for Dwyer's satisfaction. It was therefore proposed to tie the vertebral artery, but X-rays showed the aneurysm extending from the aortic arch to the seventh cervical transverse process—almost completely covering the access to the *first* stage of the vertebral artery. I therefore ventured (I was young once) to suggest the following method of tying the second stage—needlessly, for the patient's aneurysm five weeks later had shrunk sufficiently to quash the thought of intervention, much to my callow and unchristian disappointment.

ANATOMY

In the adult skeleton the breadth of the examining thumb lies comfortably between the transverse process of the atlas and that of the axis vertebra; $\frac{3}{4}$ in. of the vertebral artery is available in this interval. Elsewhere in the neck the intertransverse spaces are comparatively small and are less easily identified. The second

[1] R. Lauenstein, *Zentralb. f. Chir.*, 1918, **45,** 149; and E. Schemmel, *ibid.*, 1918, **45,** 871.

stage of the vertebral is thus most readily exposed between the atlas and axis (Fig. 38).

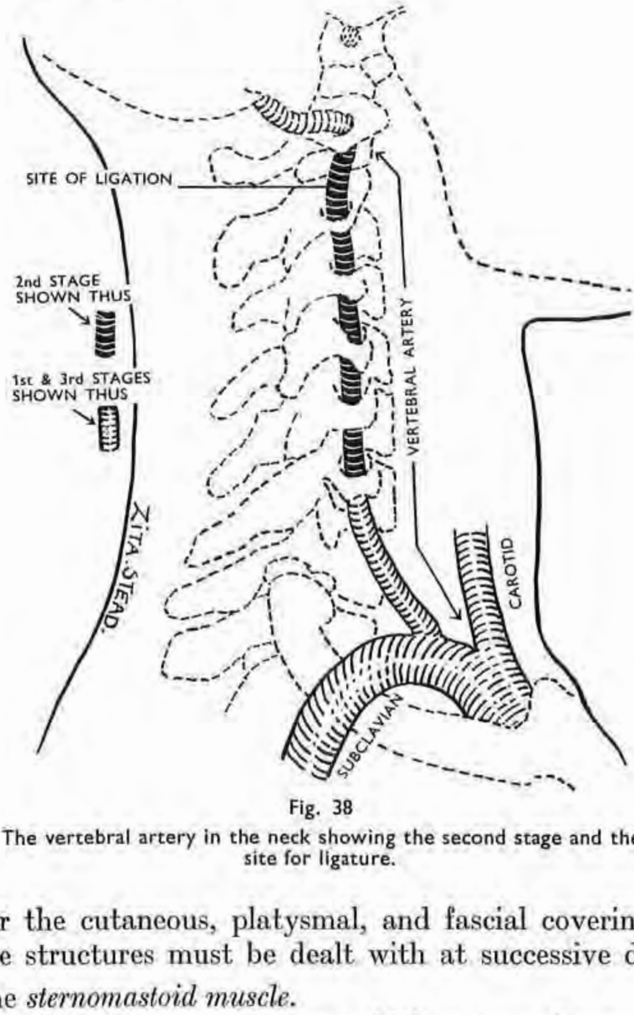


Fig. 38
The vertebral artery in the neck showing the second stage and the site for ligature.

Under the cutaneous, platysmal, and fascial coverings of the neck, five structures must be dealt with at successive depths :—

1. The *sternomastoid muscle.*
2. The *spinal accessory nerve,* which enters the muscle two (or sometimes three) fingerbreadths below the tip of the mastoid process, running as a rule in a layer of fat and often obscured by lymphatic glands (Fig. 42).
3. The dense and dubiously named *prevertebral fascia* lying deep to the fat.[1]

[1] The term 'prevertebral' applied to this fascia though acceptable to morphologists because they know it covers muscle supplied by *anterior* rami may raise some doubt in surgeons who deal with what they see. For levator scapulæ, which springs from the transverse processes of atlas and axis and from *posterior* tubercles of those of C3 and C4, lies "at the back and side of neck" (Gray), for the most part *behind* the vertebræ.

4. The stout and quite separate first slip of the *levator scapulæ muscle* arising from the tip of the transverse process of the atlas (Fig. 43).
5. The thin flat first tendon of splenius cervicis lying deep to the levator slip.

Deep to structures 4 and 5 is the first intertransverse space, bounded in front and behind by an intertransverse muscle, and containing the part of the vertebral artery to be tied (Fig. 38).

The posterior intertransverse muscle is as a rule very feebly developed and does not screen the artery. The *anterior intertransverse muscle*, too, in itself does not conceal the vessel. It is often, however, continuous laterally with the first slip of the splenius cervicis (Fig. 39) which lies deep to that of levator scapulæ and so, too, must be cut in order to open the first intertransverse space. The weak fibres of intertransverse muscle are easily divulsed.

The *internal jugular vein* (Fig. 42) is in danger during the definition of the spinal accessory if the dissection is carried *in front of* the tips of the transverse processes.

The *anterior ramus of the second cervical nerve* crosses the vertebral artery transversely and is fixed and flattened out against it by the tight translucent sheath that clothes the vessel.

Bony landmarks.—The first deep guide in this ligation is the tip of the long transverse process of the atlas (Fig. 40). It should be unmistakable when the sternomastoid

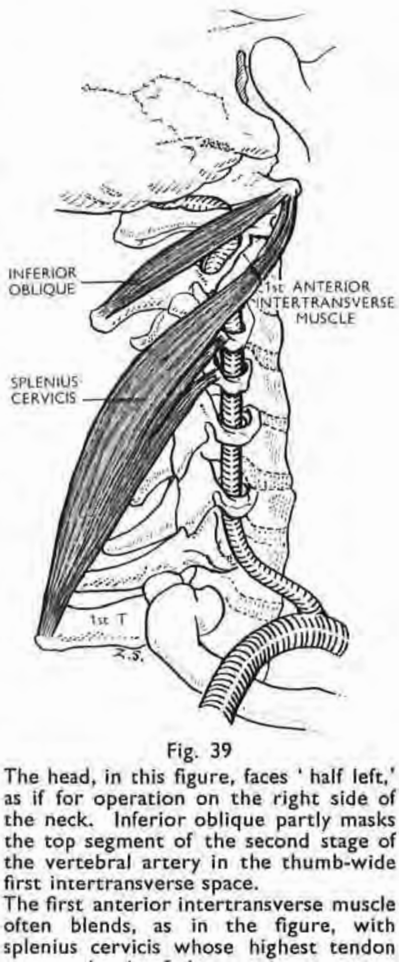


Fig. 39

The head, in this figure, faces ' half left,' as if for operation on the right side of the neck. Inferior oblique partly masks the top segment of the second stage of the vertebral artery in the thumb-wide first intertransverse space.

The first anterior intertransverse muscle often blends, as in the figure, with splenius cervicis whose highest tendon goes to the tip of the transverse process of atlas where it is covered by the highest tendon of levator scapulæ. Failure to recall this superposition of a nearly finger-thick and well-defined levator origin upon a thin and flattened splenius tendon explains why the surgeon, after easily surrounding and dividing the levator piece, so often thinks he has merely cut through part of it. So, for complete clearance of the first intertransverse space, divide levator and splenial attachments to the transverse process of atlas ; disrupt the anterior intertransverse muscle.

has been mobilised, and is felt one fingerbreadth below and one in front of the mastoid tip.

The transverse process of the axis, on the other hand, is much shorter, and may be confused with a bony eminence behind and below it which consists of the articular process of the axis and that of the third cervical vertebra. During the operation this joint becomes surprisingly prominent when the head is turned away.

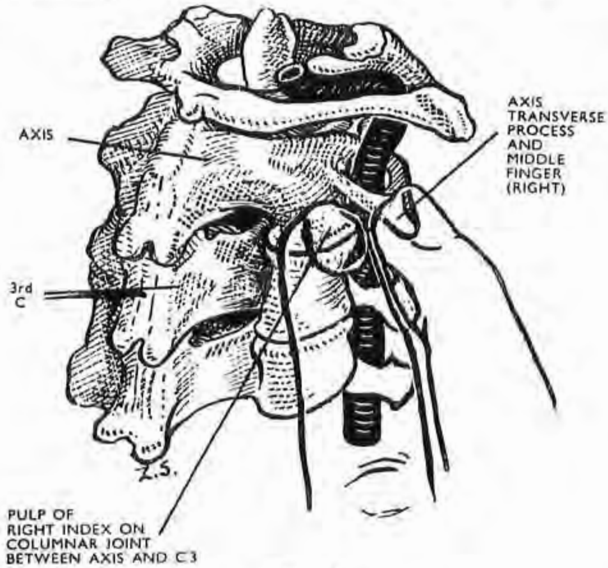


Fig. 40

Find the thumb-wide space between the transverse processes of atlas and of axis. Mark the tip of each process with recognisable forceps for easy reference throughout the operation. When the patient's head is turned away from the surgeon, the columnar joint between axis and the third cervical vertebra becomes prominent and may then be mistaken for the transverse process of axis. The figure shows how, on the *right* side, when the pulp of the *right* index finger touches the articular prominence, the adjacent middle-finger tip will touch the tip of the transverse process of axis. (Left fingers are used on the left side.)

These two bony points may be distinguished in the following way: On the right side, when the right index finger-tip of the surgeon, *pointing to the patient's head*, rests on the projecting joint, the tip of the middle finger alongside (and touching the index) rest precisely on the transverse process of the axis (Fig. 40).

THE OPERATION

Posture.—The patient lies on his back with the neck extended and the chin turned away from the vessel to be tied. This, of course, moves our main landmark: the tip of the atlas transverse process turns with the chin and lies in front of that of axis.

Incision (Fig. 41).—The skin, platysma, and deep fascia are divided along the anterior border of the sternomastoid from the cricoid level to the skull. The knife then turns back across the base of the mastoid and cuts to the bone, dividing the sterno-

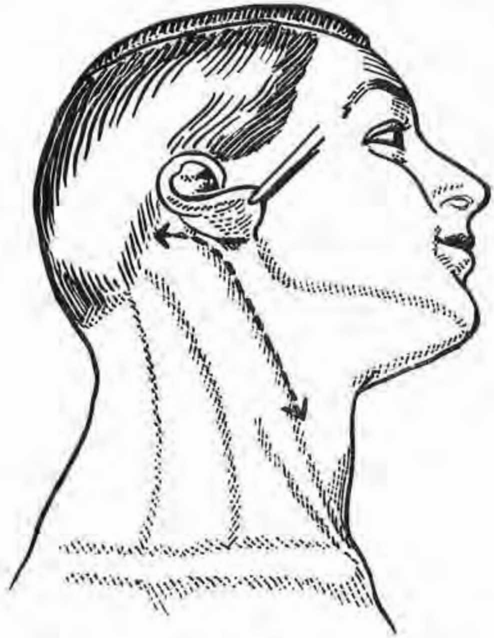


Fig. 41

Draw the lobule of the ear forward. Divide skin, platysma, and fascia along the anterior border of sternomastoid from the cricoid level to the skull. Cut backwards to the bone across the base of the mastoid, dividing the attachment which the process gives to sternomastoid and splenius capitis.

mastoid insertion with the mastoid part of the splenius capitis.

Mobilise the sternomastoid and turn it down and out through two right angles with the mastoid part of splenius (Fig. 42).[1]

Define the spinal accessory nerve, which enters the sternomastoid two (or three) fingerbreadths below the mastoid tip. In doing this avoid the internal jugular vein by keeping the dissection *posterior* to the tips of the transverse processes.

[1] This detachment and eversion of the mastoid end of the muscle is invaluable *as a first step* in the ordinary removal of cervical glands in malignant cases.

Feel the deep guide, *i.e.*, the tip of the transverse process of the atlas. Pick up and divide the thick ' prevertebral ' fascia obliquely downwards from this bony point, parallel with the spinal accessory

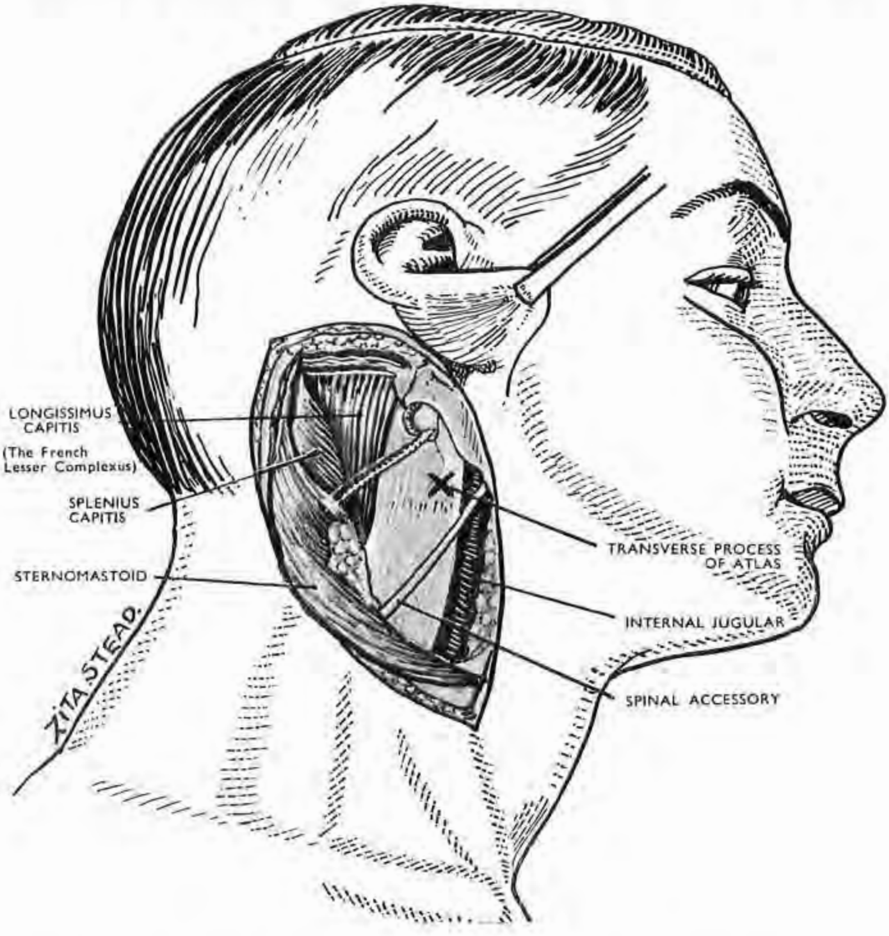


Fig. 42

Mobilise the cut fibres of sternomastoid and splenius. Turn them down and out through two right angles, exposing a layer of fat in which the accessory nerve runs obliquely. Define the nerve, and from the tip (X) of the transverse process of atlas—your deep guide—cut through the fat, above and parallel to the nerve. A thick fascia, questionably termed ' prevertebral,' is thus exposed ; divide it along the same line as the fat. Locate the tip of the cervical transverse processes and work *behind* them to avoid injuring the internal jugular vein.

(Fig. 43). The stout, and quite separate, origin of the levator scapulæ from the atlas transverse process is thus exposed. Define it just below the atlas in the same way as a vessel is defined : use an aneurysm needle and divide the muscle upon it. A few shreds of muscle disturbed by the needle will often remain (anterior intertransverse fibres); divulse these. Raise and divide the thin first tendon of splenius cervicis on the needle.

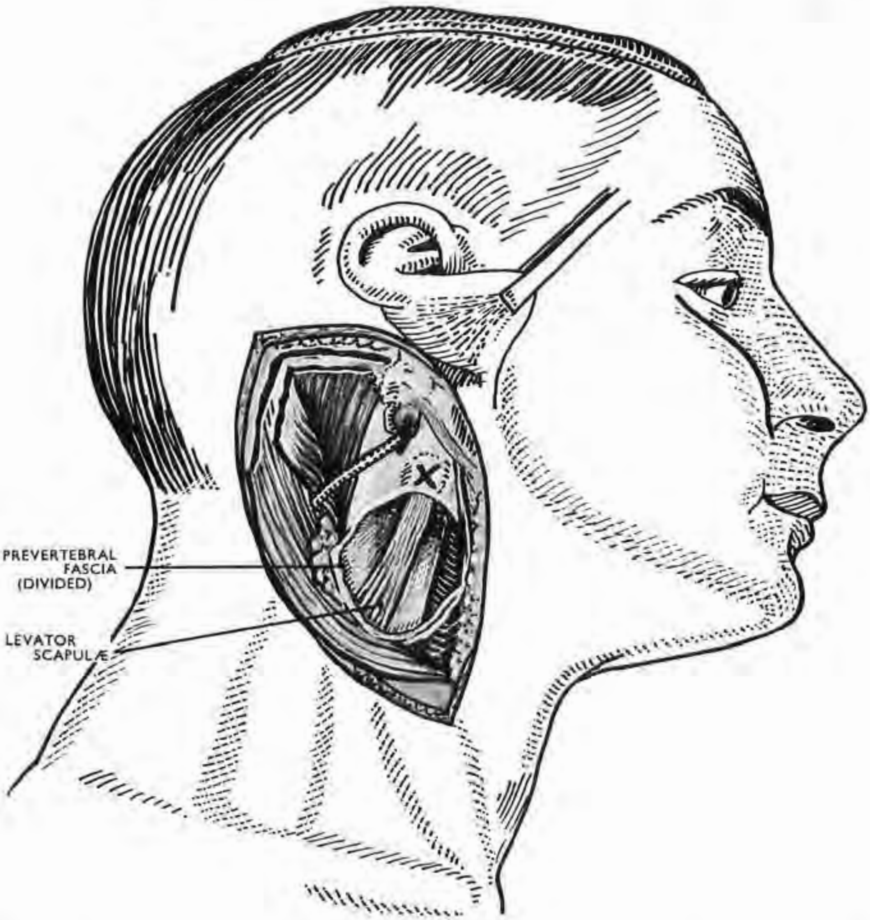


Fig. 43

Division of the so-called prevertebral fascia exposes the topmost and quite separate slip of levator scapulæ.

The vertebral artery is then seen passing up, forwards, and out in the space between axis and atlas. It is crossed here at variable heights by the anterior ramus of the second cervical nerve, and this irregular location, together with the squeezing of the ramus by the tough perivascular sheath, may retard its detection. The nerve swells surprisingly once the sheath is opened.

The simplicity of the operation depends on a lively and constant regard for two bony points—the ipsilateral tips of the transverse processes of atlas and axis: *In all positions of the head the line joining their tips overlies and is parallel with the relevant*

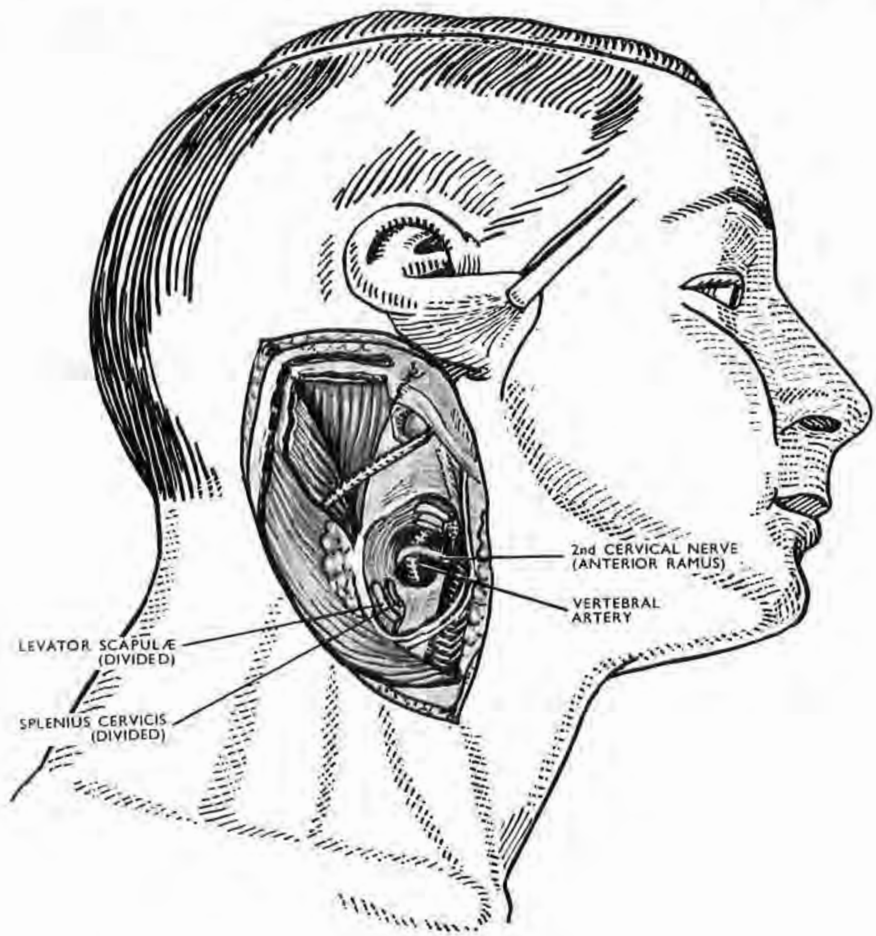


Fig. 44

Pass an aneurysm needle around the slip of levator scapulæ *as if it were an artery.* Deep to it lies the topmost slip of splenius cervicis (Figs. 39 and 50) ; divide this, too, and divulse adherent shreds of anterior intertransverse muscle. The vertebral artery, crossed by the anterior ramus of the second cervical nerve, is then exposed in the thumbwide intertransverse space between atlas and axis. The nerve is so tightly bound to the vessel that it may be difficult to see till the tough, thin sheath is opened.

piece of vertebral artery. A Michel clip fastened over each bony point keeps them in view.

EXPOSURE OF THE SECOND STAGE FROM C2 TO C6

This portion of the artery lies in the channel formed alternately by tunnels that pierce cervical transverse processes and the spaces that separate them. The vessel can be exposed in continuity if we resect appropriate parts of *costal* elements of vertebræ from C2 to C6, after a full sternomastoid eversion.

Two prevertebral muscles—longus colli and longus capitis—lie immediately in front of these costal objectives, and must be mobilised and drawn outwards. To reach these muscles, say on the right side, displace the right carotid bundle leftwards, and with it the larynx and pharynx after dividing the short sagittal mooring that links the common sheath of the cervical viscera to prevertebral fascia (Fig. 45). Then deal with longus colli.

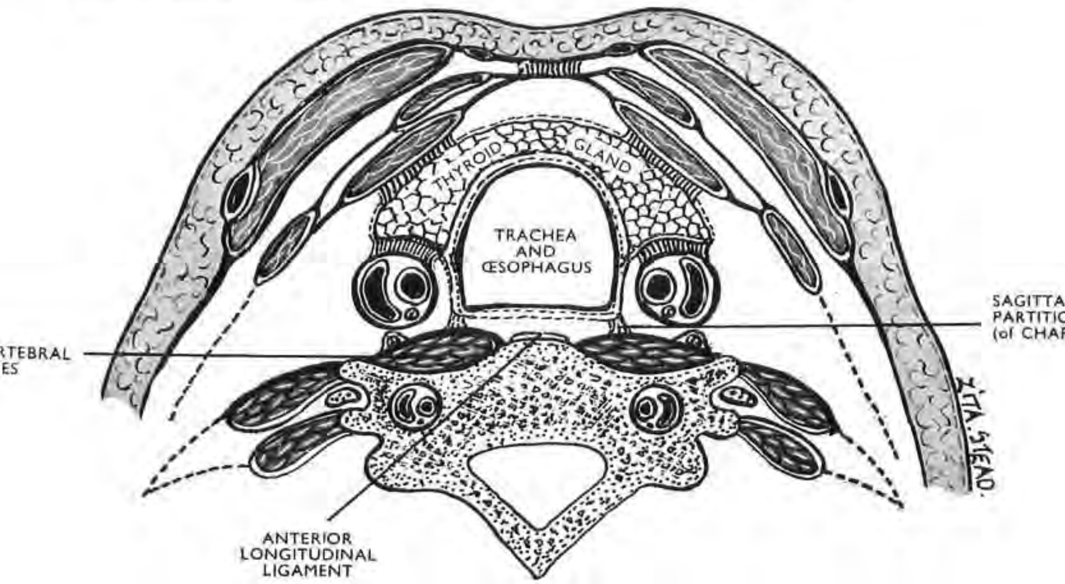


Fig. 45

The visceral compartment of the neck containing thyroid gland, trachea, and œsophagus. At a higher level of section the compartment contains larynx and pharynx. The figure shows (1) how the sagittal partitions of Charpy—which are easily disrupted or stretched—moor the viscera, but very loosely, to prevertebral fascia and bound the retrovisceral space ; it also shows (2) how the retrovisceral space will allow of visceral displacement when one of the sagittal partitions bounding it is either broken or stretched ; (3) how there is a relative solidarity between the cervical viscera which permits of *en masse* movement not only vertically as in swallowing, but also *transversely*, thus allowing exposure of the interval between right and left prevertebral muscles. The figure shows that there is sufficient union between the carotid bundle and the visceral compartment to let the bundle share in the *en masse* sideways movement ; and (4) how the median part of the anterior longitudinal ligament lies uncovered between prevertebral muscle fibres on either side. We can thus work from *there* when we detach longus colli from the vertebral bodies (See also Fig. 46).

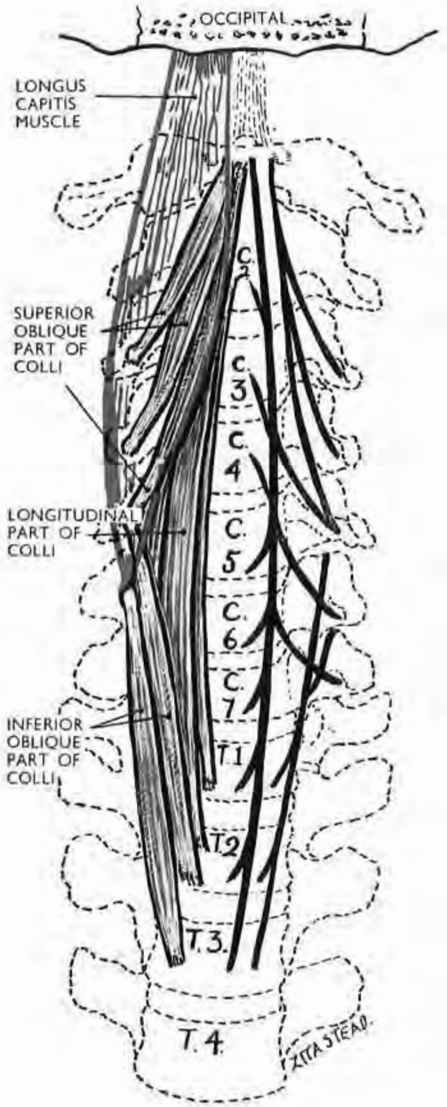


Fig. 46

The three parts of longus colli (in black) : longus capitis (in red) seen from in front

The longitudinal part of colli and the 'red muscle' (capitis) sandwich the upper oblique part of colli. When, therefore, we detach the deep longitudinal part of colli from the vertebral *bodies*, the whole sandwich—longitudinal part of colli, the upper (intervening) part of colli, and longus capitis—can be turned out towards the anterior tubercles ; for these tubercles are now the sole remaining attachments of its relevant parts.

The 'vertical' part of colli (Fig. 46).—This part (whose fibres curve gently and are vertical to nothing) is the key to the position : it is the most medial and deepest component of a tripartite muscle ; it lies behind two *oblique* components, an upper and a lower. The *lower* oblique is the smallest and most variable of the three[1] ; it slopes up and out from bodies of T3, T2, T1 to anterior tubercles of C6 and C5. The *upper oblique component* slopes up and in from anterior tubercles of C6, C5, C4, and C3 to the lateral face of the tubercle on the anterior arch of atlas.

Important and powerful additions pass with an upward and inward slant from costal elements of C5, C6, C7 to join the deep 'vertical' part and seem to determine the actual outward curve of its fibres. The gently curving 'vertical' fibres are attached only to vertebral *bodies*—the lower moiety from T3 to C5, the upper from the anterior tubercle of atlas to C4. (As the state of longus colli attachments escapes concise description, I give an orthodox account.)

[1] According to the high authority of Le Double, longus colli is "the most variable of all muscles in the human economy"—a remark which applies in chief to the number of its attachments. The basic tripartite *plan* of colli is, however, as constant as anything in myology.

The crucial disc.—The transition, therefore, of ‘ vertical ’ fibres from so-called origin to so-called insertion (or better, from upper to lower moiety) takes place at the disc between C4 and C5. For that reason the infinitesimal ‘ stripping angle ’ (p. 5) which the longitudinal fibres of colli make with vertebral bodies opens downwards above the disc and upwards below it. A rugine, therefore, introduced medially at the level of this crucial disc will best detach the ‘ vertical ’ part of colli by working *into* those unseen but important angles—upwards above the disc, downwards below it.

Fortunately for our purpose in these pages, a midline fusion of right and left ‘ colli ’ (normal in herbivoræ, where the two form a single muscle) is very rare in man, so that, except near atlas, a thumbwide space separates them and leaves the vertebral bodies clothed only by anterior longitudinal ligaments. The presence of this interspace holds a special benefit: it shortens the distance through which we need to shift larynx and pharynx in order to make the medial border of colli accessible for detachment.

Very rarely longus capitis will fuse with its fellow across the middle line and cover the interspace between the two colli muscles —a rub to test the art of surgery.

Longus capitis (formerly rectus capitis anticus major).—This, which is the only other muscle immediately concerning us, covers all but the inner edge of the *upper oblique* part of longus colli. The longus capitis is the more anterior, more lateral, and more bulky of the two prevertebral muscles; it forms with the ‘ vertical ’ fibres of longus colli a sandwich whose ‘ filling ’ is the upper *oblique* part of colli (Fig. 46). (Capitis often springs, as shown here infro‘pəɩ mC3 to C6; it may also join with the lower oblique part of colli and thus get origin from thoracic *bodies*.)

When, therefore, we detach and displace the ‘ vertical ’ part of longus colli outwards, that muscle will carry off with it the two bellies that lie on its anterior face—(1) its own oblique upper belly, and (2) the major part of longus capitis. This clearance of muscle attachments from the front of a body and a transverse cervical process must reach to and *stop* at the medial side of the relevant anterior tubercle. A path is thus cleared to costal processes from C3 to C6.

If, however, we wish to include in our exposure the vascular segment encircled by the foramen transversarium of C2 we must divide the topmost tendon of the upper *oblique* part of colli—a part that is *not* covered by capitis and reaches (with 'vertical' fibres) to the tubercle on the anterior arch of atlas (Fig. 46).

The groove marking the relevant piece of costal process.—Displacement of the prevertebral muscles lays bare a shallow longitudinal groove on the front of each transverse process from C3 to C6—a groove just wide enough to lodge the tip of a little finger (Fig. 47).

The groove is bounded *laterally* by the anterior tubercle whose apparent size is magnified by scalene attachments; *medially* by a flatter prominence, more diffuse in character, which *looks* as if the rib-head of a plastic costal rudiment had spread against and stuck to the side of its own vertebral body. Each rib-head thickening has an upward projection or apophysis, semilunar in shape, whose 'free' upper border is like the curved edge of a trimmed finger-nail, and about as long. The semilunar apophysis overlaps the lateral side of the intervertebral disc next above it and bounds the so-called 'unco-vertebral' joint [1] of Trolard.

Each groove, from C2 to C6, exactly covers and (except for a part of vertebral vein and sympathetic nerves) lies next the vertebral artery as it goes through a foramen. The bone forming the floor of the groove is about as thick as the toe-nail of a big toe. It is most safely resected by using a rongeur forceps whose blunt nose has the same width as the groove which it must span, grasp, and bite through from upper to lower edge provided it bite shallowly and with great caution (Fig. 47).

The anterior rami of cervical nerves lie opposite the groove but *behind* the artery. Immediately lateral to the groove, however, the rami curve so sharply forward round the artery that if the anterior tubercle of a transverse process is removed, the numerically corresponding ramus just below it is likely to be hurt.

The special case at C2.—The foramen transversarium of axis is unlike those from C3 to C7 in two respects: (1) it is not bounded in front by a thin grooved scale of bone but by an ungrooved bar about $\frac{1}{5}$ in. in diameter; (2) its direction is not vertically upward, but slopes up and out, making an angle of some 45 degrees with the transverse plane of the neck. The slope of the artery corresponds to that of the foramen.

[1] Poirier (*Traité d'Anatomie Humaine*, 2ème Edn., 1899, T.I., p. 794) states that these joints were "dimly perceived" by Barkow, well studied by Luschka in 1858, and named by Trolard of Algiers in 1892—not very happily, however, for uncus means a hook, while these apophyses are not hooked like claws but concave like fingernails on their deep aspect. Unguiculo-central or, better, costo-central, might denote the joints they bound, for they are in series with thoracic articulations between rib heads and vertebral bodies.

Before dividing this bony bar locate the single tubercle of the transverse process of axis. Using a rongeur, divide the bone from in front at the inner side of the tubercle. Cut piecemeal and posteromedially. The length of the oblique cut will be $\frac{1}{4}$ in.

The venous accompaniment of the vertebral artery.[1]—The vertebral vein while in its second (transversarial-intertransverse) stage is fed chiefly from cervical vertebræ, each a capacious reservoir. Serial sections show that the semilunar outline of this

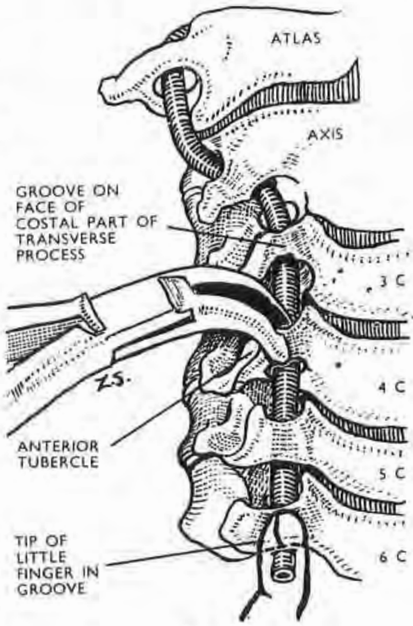


Fig. 47

The costal face of each cervical transverse process, except the first and second, shows a longitudinal groove. The groove just fits the tip of a little finger. It is bounded laterally by the anterior tubercle of the process; medially by a low, placenta-shaped thickening, such as the head and ligaments of a recessive rib might make in fusing with the relevant vertebral body. (The free, upper edge of the thickening helps to form a Luschka's joint.)

Resection of the grooved part of the costal face—which has the thickness of a big-toe nail—reveals a transversarial segment of the vertebral artery. The anterior ramus of a cervical nerve lies directly behind each of these arterial segments.

[1] A network called the suboccipital venous plexus permeates the mass of fat in front of the complexus; it is largely made up of tributaries from adjacent muscle. The plexus is at once a link and a source. *As a link*, it unites three deep cervical veins—vertebral, profunda cervicis, and (when present) posterior jugular—with the collar-like plexus on the atlas ring, immediately below foramen magnum. Here the basilar sinus joins with the occipital sinus. The vertical depth of the collar thus formed is supplemented by the topmost reach of veins that have either just been lining the inner face of the spinal canal or else have coated the outer face of cervical vertebræ.

As a source, the suboccipital plexus is the principal origin of the three deep veins already mentioned. The vertebral and posterior jugular have a common origin on the atlas arch; the deep cervical vein arises more laterally nearer the mastoid process. At the root of the neck deep cervical and posterior jugular each pass forward between the transverse process of C7 and the neck of first rib; the deep cervical joins the vertebral vein, which it often exceeds in size, while posterior jugular (like the vertebral) enters the innominate. *Posterior* jugular, like profunda cervicis, lies behind the cervical transverse processes, but more medially, and like profunda, it, too, enters the innominate vein after passing between the neck of the first rib and the transverse process of C7. The small *anterior* vertebral vein, which begins as a plexus round cervical transverse processes, enters the lower end of the vertebral, and an *accessory* vertebral vein may leave the foramen in the transverse process of C7 and join the innominate. If these facts are not anticipated the multiplicity of veins close to the stellate ganglion may cause surprise.

All these veins anastomose among themselves so freely that they are often able to deplete the cranial cavity when the anterior, external and internal jugular veins are blocked by strangulation, leaving the face congested and the brain blanched (Charpy).

vein embraces the lateral curve of the arterial wall, and that though single above, the vein is apt to duplicate below and to give downward branches that have special bony channels formed by subdivisions of some or other of the transversarial foramina.

At each intertransverse space of the neck the main vertebral vein receives an influx brought by some twenty to sixty tributaries that pass out with spinal nerves through each intervertebral foramen—a fact that might seem to make approach to them less attractive than one directed to segments that are bone-encircled. Also it is worth noting that while the vertebral artery is relatively free in its osteofibrous canal, the principal vein (whose task, apart from draining spinal cord and nerves, is to drain bone) is *fixed*: to bone in transversarial foramina; to fibrous tissue in the intertransverse spaces.

Experience shows, however, that although it is impossible to expose any part of the second stage of the vertebral artery without wounding the vein or its tributaries, *styptic* hæmostasis, with muscle shreds or otherwise, is easily obtained in the narrow track of the vertebrals.

The risk of air embolism.—This accident seems *not* to have happened in man in connection with the surgery of vertebral vessels but is none the less worth considering. The main vertebral vein is, we saw, bound to bone or fibrous tissue so that its lumen when cut into is likely to gape. Air embolism by way of vertebral veins is therefore not impossible; it was, in fact, as François Franck proved, a special cause of death in dogs whose cranial diploe was opened; for the vertebral vein of dogs has far more importance than their tiny internal jugular, and is, in them, the chief path by which blood returns from head and neck. It may be that in man the restricted size and semilunar shape of the vertebral vein are safeguards. But time alone will show whether a prophylactic ligature of the lowest or 'free' stage of the vertebral vein, in prelude to exposure of the second stage of the artery, would be a wise and justifiable procedure—or just 'plain yellow.' In such matters Hegel's advice is good: "Obey your conscience, but remember that you may have the conscience of an ass."

THE VERTEBRAL ARTERY

THE FIRST STAGE, WITH RELATED STRUCTURES

After we have mobilised the lower part of sternomastoid and turned it out through two right angles (p. 56), we must displace the carotid bundle inwards. For this nothing could serve us better than the complete absence of lateral branches or tributaries stemming from or entering the common carotid portion of the bundle: *its vascular ties are on one side only*—a fact in daily use, which though unique in the anatomy of large vessels is not, so far as I know, mentioned as worth notice.[1]

It happens, too, that both posterior branches of the *external* carotid have a lengthwise course in the neck and so will not hamper the medial movement of the bundle.

These opposite displacements of bundle and sternomastoid reveal an arched disposal, single on the right, double on the left.

THE ARCHED STRUCTURES (Fig. 35)

On the left side the thoracic duct curves out behind the carotid sheath; somewhat higher up, but on a deeper plane, the inferior thyroid artery curves in. On the right, the right lymphatic duct is surgically negligible, and only the *thyroid* arch needs attention.

The arch of the thoracic duct.—On the left side, the top of this lymphatic arch lies two or three fingerbreadths below the carotid tubercle of Chassaignac. This tubercle which projects forward from the transverse process of the sixth cervical vertebra is often small and in most persons owes its prominence and palpability less to its own size than to the rather sharp recession of the seventh process in the region where the forward curve of bodies of cervical vertebræ begins to blend with the backward curve described by the upper dorsal bodies.

Find this arch, which runs in a potentially tough blend of fat and small lymph glands, at the place where it nears the junction of internal jugular with subclavian to end—by a blue $\frac{1}{4}$-in.—in either. It will then be seen that when sternomastoid has been

[1] *Farabeuf's triangle.*—This is another useful and neglected feature of carotid anatomy which forms an admirable rallying point in the neck. The triangle is bounded laterally and *behind* by the internal jugular vein; *in front*, by the stem of the common facial vein (which often conforms to the term thyro-lingual-facial); *above*, by the forward curving of the hypoglossal nerve which is the base of the triangle. The *floor* of the triangle is formed by the carotid bifurcation and is roughly bisected by the descendens hypoglossi nerve.

turned outwards (after dividing omohyoid and the anterior jugular vein), all closely related structures, *excepting* the carotid bundle, lie on planes immediately behind this arched portion of thoracic duct. When found and mobilised the ductal arch can for the moment be pushed down behind the clavicle.

The arch of the inferior thyroid artery, and the thyrocervical trunk from which it rises, are next dealt with. The arch lies about a fingerbreadth below the carotid tubercle, and the trunk is often held laterally by two transverse branches—the suprascapular behind the clavicle and, higher up, the transverse cervical. If these vessels prevent displacement of the arch, tie and divide them. Open the prevertebral fascia close along the *medial* side of the phrenic nerve which shows through this covering, taking care not to injure scalenus anterior. Catch the medial lip of the divided fascia and use it to envelop and retract the thyroid arch which it will thus draw inwards. With the arch goes the close-linked middle sympathetic cervical ganglion. The ascending cervical artery and possibly the anterior vertebral vein (which it is important not to slit lengthwise) are also rolled cigarette-like in the fascial wrap. The phrenic nerve remains *in situ.*

The broad arrow of the vertebrals.—This cigarette-rolling retraction exposes the angle formed below the carotid tubercle by the almost vertical edge of longus cervicis meeting the outward slant of scalenus anterior. Below the tubercle the vertebral vessels divide the angle and thus form the shaft of a kind of broad arrow. Near the tubercle the vessels are covered by an overlap of muscle, but, after the fascia has been rolled off, they lie bare some three fingerbreadths below that landmark. At this level the vertebral vein is anterior to the artery, but lower down it moves out and *forward*, going thus in front of the finger-thick subclavian artery to reach the back of the innominate or the subclavian vein.

Thus, merely by turning the lower part of sternomastoid out through two right angles, and the dividing prevertebral or more accurately prescalene fascia—using the fascia to draw aside arched intervening vessels—we can expose the whole first stage of the right or left vertebral artery down to the origin of either from the first stage of the subclavian trunk.

THE FIRST STAGE OF THE SUBCLAVIAN ARTERY, ITS BRANCHES AND THE STELLATE GANGLION

These structures, we have seen, become visible while exposing the first part of the vertebral trunk by the method just described.

Of the other subclavian branches the whole thyrocervical trunk is already bare, while the costocervical trunk can be traced to the first rib where it divides into deep cervical and superior intercostal branches. The start of the internal mammary artery appears, with the phrenic nerve slanting behind it or in front. The cervical moiety of the stellate ganglion lies behind and between the paths of two arteries—the vertebral which goes upwards, the costocervical trunk which slants out. At the outer side of the vertebral artery the top of the ganglion gives off a short, usually threefold, band—the vertebral nerve of Cruveilhier—that enters the transverse process of the sixth cervical vertebra.

This cervical part of the stellate often slopes, surprisingly, out and down, and then continues with the first ganglion of the thoracic trunk—marked from it by a mere notch or waist. The part of stellate corresponding to the first thoracic ganglion lies in front of and frequently along the neck of the first rib, separated from the subclavian artery by the apex of lung and pleura, and by suprapleural membrane. Against the neck of this rib the ganglion is often felt as a rubbery thickening by the pulp of a finger passed down through the thoracic inlet so that it will find and touch the *outer* side of a small bony lump which marks where the head of the first rib joins the first thoracic vertebra. If then we tie and divide the costocervical trunk and depress the pleural dome over which the trunk has curved and acted as a mooring, the arch of the subclavian artery can be coaxed forward *and in* towards the vertebral artery, exposing completely the part of the stellate ganglion that lies behind the arch, sandwiched—now that pleura is depressed—between the arch and the catapult fork of the eighth cervical and first thoracic nerves, whose handle crosses the first rib as the lowest trunk of brachial plexus. Striping the front of the ganglion (and thus included in the sandwich) is the highest posterior or intercostal vein which may hook forward below the subclavian artery to reach the vertebral vein or the innominate.

THE LEFT SUBCLAVIAN ARTERY

Apart, however, from dividing any branch, finger dissection through sound tissue will isolate the *left* subclavian artery and leave it free and visible for easy access down to its origin from the aorta, whose arch is felt and seen in the depth of the thorax (Fig. 48).

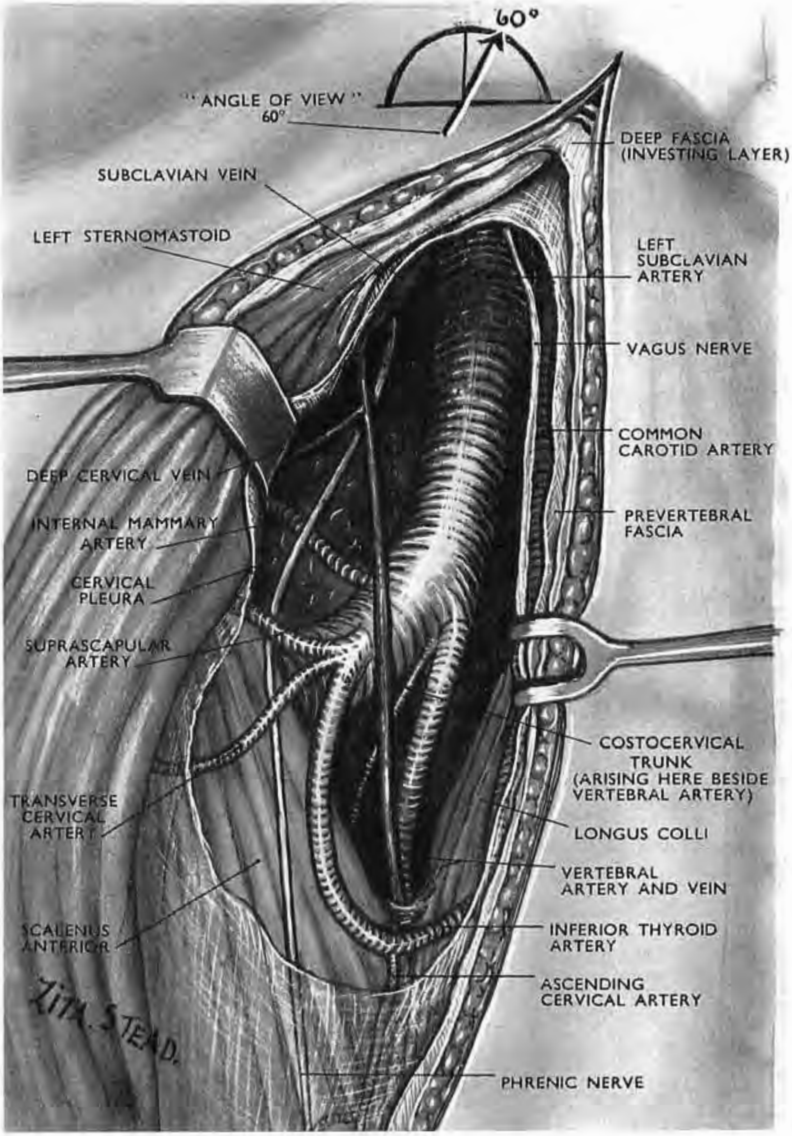


Fig. 48

The root of the neck after full eversion of the left sternomastoid

The surgeon standing at the *left* of the patient's neck looks along the arrow which makes an angle of 60 degrees with a transverse plane passing through the carotid tubercle of Chassaignac on the sixth cervical vertebra.

Note.—The thoracic duct has been thrust down out of view behind the clavicle. The jugular vein is omitted to simplify the picture.

The aortic arch could be felt and glimpsed at the base of the subclavian trunk, and it is easy—again in the absence of impassable adhesions—to tie the subclavian at that spot.

The previous medial displacement of the carotid bundle has removed the vagus nerve from our path ; the phrenic falls away with light pressure. (Throughout this procedure the thoracic ductal arch has lain where we thrust it, down behind the clavicle —crumpled but in no way injured.)

Before they are disturbed the left phrenic and vagus nerves *cross each other at the level where the arch* of the subclavian artery begins, the phrenic passing anteromedial to the vagus. The nerves thereafter keep this relation as they go apart to reach the left or ventrolateral side of the aortic arch.

THE WHOLE SUBCLAVIAN TRUNK

Our exposure can, of course, be extended to the third stage of the right or left subclavian artery (p. 53) ; and all three stages are seen in continuity when scalenus anterior is divided after safeguarding the phrenic nerve.

A plethora of veins.—The profunda vein passes between the neck of the first rib and the seventh cervical transverse process, receiving on its way a vein from the upper one or two intercostal spaces ; then it lies over the top of the pleural dome and loops forward from the pleura below the subclavian arch to reach the lower end of the vertebral vein, which terminates in the innominate. When, however, as in this present exposure, the pleural dome has been depressed, the profunda vein, carrying its superior cervical tributary, falls back against the front of the thoracic part of the stellate ganglion where it lies *medial* to its fellow-artery. Beside it, too, may lie a posterior jugular vein (p. 71). This, when it is present, ends in the innominate behind the vertebral, with which it sometimes joins.

THE INNOMINATE ARTERY

On the *right* side the lower part of our everted sternomastoid approach will reach the innominate bifurcation behind the upper part of the sternoclavicular joint.[1]

And there, again, in sound tissues mere finger dissection can

[1] Those who take anatomy from text-book figures instead of from the body may be surprised to find the right subclavian artery rising quite so closely up the back of right carotid, recalling otherwise the less immediate relationship of ulnar to radial artery at the normal forking of the brachial trunk—a feature that is constantly misdrawn. For artists are allowed (or are they urged ?) to show the whole fork flat, as if it all lay in a single frontal plane of the extended supine limb.

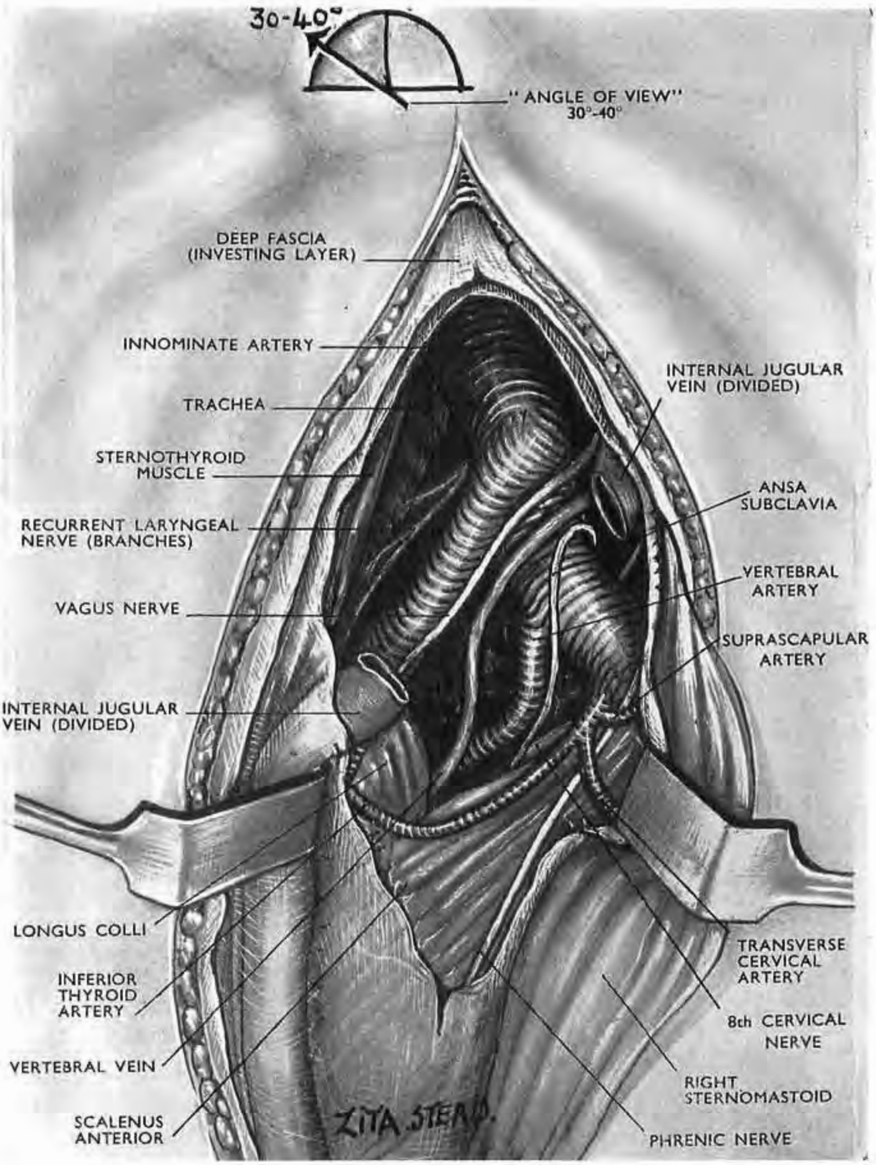


Fig. 49

The root of the neck after full eversion of the right sternomastoid

The surgeon standing at the *right* of the patient's neck looks along the arrow which makes an angle of 30 to 40 degrees with a transverse plane at the carotid tubercle of Chassaignac on the sixth cervical vertebra. The right ansa subclavia, which was here a single band like that found normally on the left side, is often divided into from two to six parts. The aortic arch can be glimpsed and felt, and—in the absence of intervening aneurysm or adhesive lesions—the innominate artery can be tied where it arises.

(To simplify the picture, structures are viewed through a gap in the internal jugular instead of by retracting that vessel.)

carry the exposure of this large vessel down to the aortic arch (Fig. 49). The easy path for the finger is by the medial side of the *carotid* between that trunk and the trachea ; for passing down along the right subclavian the finger may be caught in one or other of three neural loops that clasp the artery : ansa subclavia, the right recurrent laryngeal nerve, or, farthest out along the first stage of the vessel, the loop of strands that join the phrenic to the upper end of stellate ganglion.

It is, of course, obvious that these deep, aortotropic descents into the chest are only possible in the absence of local adhesive invasion, and for the moment their precise application escapes me. But, for my part, it would be ungrateful, and indeed unwise, on that account to damn these excursions as useless. I have therefore described them, letting them wait their season : "In the long lapse of time there is nothing that may not happen."

ARTERIAL VARIETIES AT THE ROOT OF THE NECK

In the preceding paragraphs I have described arrangements which Quain (who was wise in these matters) refers to as 'usual' —writing the word between inverted commas. In that spirit I have dealt, for example, with the arches at the root of the neck, but with full awareness of their wide range of variation.

My own experience in that region reminds me of the dangerous jest made by a Berlin comedian before the last war. "*We* all know," he said, "that 99 per cent. of the German people are strong for the Fuehrer, but wherever I go—in bus or train or tram—I meet the 1 per cent." I shall therefore be content to indicate departures from the 'usual,' neglecting their percentage happening, since figures that proclaim infrequent incidence no more preclude the surgeon from meeting an example than they will save unlucky persons from death by lightning.

But departures from Quain's 'usual' arrangements give least trouble when we know they exist ; then, a wide access lets us see and deal with them.

They can be grouped (by the help of a little mythology) under six headings, which 'explain' their mode of origin as follows :—

1. **Absorption.**—If we imagine a fictitious process of this kind occurring, say, at the thyrocervical trunk, some or all of its three branches (suprascapular, transverse cervical, inferior thyroid) will then arise *directly* from the subclavian artery with the occasional addition of the ascending cervical.

2. **Fusion** with a neighbour may produce a *left* innominate artery, plus the 'usual' right.

3. **Multiplication.**—Two right vertebrals may spring separately from the subclavian and unite higher up the neck—a natural extension of those *single* vertebral trunks which spring by more than one root.

4. **Deficiencies.**—These create the need for 'replacement' variations—as when a superior thyroid branch supplies the *back* of the gland in the absence of an inferior thyroid artery; or when the inferior thyroid comes, as a rare anomaly, from the common carotid; just as either the deep branch of the transverse cervical or the suprascapular artery may spring (as they often do) directly from the third stage of subclavian.

5. **Transposition.**—A left innominate artery often arises from an aorta arching to the *right.*

6. **Embryological Shift.**—A right subclavian springing from the descending (dorsal) aorta may cross up to the right behind the œsophagus. (I met one once associated with a plunging goitre.)

Displacement of the sternal end of sternomastoid.—If access to the lower end of the wound is cramped by the presence of an enlarged thyroid gland, more freedom can be got by mobilising the sternal tendon of sternomastoid—cutting through skin and fascia at its medial edge and slipping the tendon, *which is flat and finger-wide when relaxed,*[1] outwards across and past the knob-like medial end of clavicle. (It is easy to do this without injuring the sternoclavicular ligaments.)

A LATERAL APPROACH TO THE FIRST, SECOND, AND THIRD POSTERIOR CERVICAL RAMI

Exposure of this group of nerves is simplified by an exact use of the method I shall presently describe—a method based on bony points and on a gleam of fat which in the wilderness of nuchal muscle takes the eyes like a pool. Dissecting binoculars give the deep parts of the operation a final clarity.

[1] Like the proximal tendon of adductor longus and the distal tendon of biceps femoris. All three tendons become cord-like when taut, with a V-shaped cross-section.

OPERATIONS FOR SPASMODIC TORTICOLLIS

Unilateral section of these three rami plus section of the opposite accessory nerve was carried out in 1888 by two surgeons, Gardner of Adelaide and Keen of Philadelphia, for spasmodic torticollis. The aim of the operation is to paralyse each twitching muscle.

When, for example, spasms turn the face to *rightward* and throw the head back, then, *on the left side* we must paralyse the left sternomastoid and left trapezius by cutting the left accessory nerve plus branches of the left anterior rami from C2 and C3 in relation to sternomastoid, and for trapezius from C3 and C4.[1]

On the right side we must paralyse splenius capitis, longissimus capitis (the lesser complexus of the French), semispinalis capitis (our own complexus), together with the two right obliques plus the right recti posteriores of the head, by cutting right posterior rami of C1, C2, C3, and also (if the right trapezius is condemned) the ipsilateral nerve or nerves supplying it.

Binnie, by no means a timorous counsellor, characterised the procedure as " very complicated, and for most surgeons inadvisable " ; and the description he quotes of the operation, taken from R. Kennedy's (*British Medical Journal*, 3rd October, 1908), explains why it was not " a glittering success " : it left the surgeon deplorably unpiloted by landmarks.

Dandy (*Archives of Surgery*, 1930, **20**, 1021) made use of laminectomy to reach and cut the motor and sensory *roots* of C1, C2, C3 with, in addition, intrathecal section of both accessory cranial nerves. But even so he felt obliged to add a further section of each accessory nerve in the neck. His operation, dividing motor roots, must of course be followed by paralysis of unoffending muscles supplied by *anterior* rami.

Apart, however, from cases of spasmodic torticollis, the lateral approach by turning back the occipitomastoid attachments of

[1] There has been recurring doubt about the motor function of *anterior* ramal contributions that enter sternomastoid from C2 and C3. Claude Bernard in 1858 concluded that division of the spinal part of the accessory knocked out sternomastoid as a ' muscle of orientation,' leaving it to act merely as a respiratory muscle, and then only during deep inspiration. According to Sternberg (1898) the sternomastoid receives all its motor fibres from the accessory nerve, the role of the supply from anterior rami of C2 and C3 being purely sensory. More recently K. B. Corbin and his associates, Yee and Harrison, have proved that in rabbits, cats, and monkeys the cervical contributions to the innervation of sternomastoid and trapezius, coming from anterior rami of C2, C3, C4, and joining with the extracranial part of the accessory nerve, carry no motor fibres to those muscles but are entirely proprioceptive in function. " It seems," say the authors, " reasonable to conclude that a similar condition obtains in man." (*Journal of Comparative Neurology*, 1938, **69**, 315 ; 1939, **70**, 305 ; *Brain*, 1939, 191.)

sternomastoid and splenius has, I think, a special application for lesions with deep, central scarring like the following :—

A naval officer slipped on the companion-ladder of a destroyer

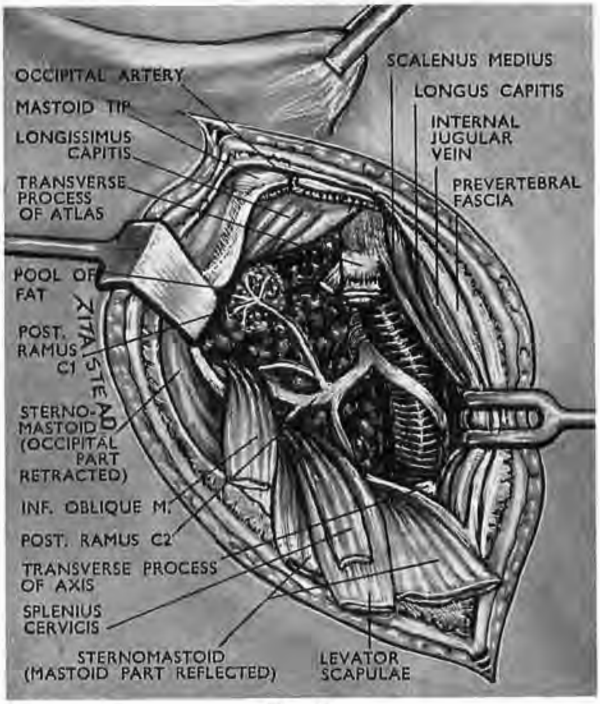


Fig. 50

The small pool of fat. (The parts are shown magnified by 1½ : the true length of the segment of vertebral artery is a thumbwidth)

The first stage of the exposure is similar to that for the seat of election of the vertebral artery in the thumbwide space between the transverse processes of atlas and axis. In addition the inferior oblique muscle has been detached from atlas and turned down and back, revealing the pool of fat that bathes the five-fold branching of the posterior ramus of C1. The trunk of C2 is seen dividing into anterior and posterior rami. (The anterior ramus—flattened and fixed against the vertebral artery—is not labelled.) At the tip of the atlas transverse process three muscles have been divided—levator scapulæ ; deep to it the upper slip of splenius cervicis ; and medial to both, the inferior oblique.

Longissimus capitis is the small complexus of the French.

The internal jugular vein is the sole hazard ; its medial retraction has exposed scalenus medius (which here reached atlas) together with longus capitis.

and fell on his head with the neck in acute flexion. During the ten years which elapsed before I examined him he had suffered from severe occipital neuralgia running to the vertex and requiring a heavy and increasing aspirin dosage for sedation. Below the occiput and to the left there could be felt a dense curled mass deep in the neck. This, I believe, was the detached and rolled up ligamentum nuchæ. The upper portion of the left complexus (semispinalis capitis)—the part supplied through the posterior rami of C1, C2, C3—was completely wasted, the motor twigs having apparently been wrenched out or broken during the extreme neck flexion, leaving the main sensory portion of the greater occipital (C2) to be caught and squeezed by scar.

ANATOMY AND THE OPERATION

To avoid repetition I shall unite structure with procedure in a single account. Detachment of sternomastoid as with exposures of the vertebral artery will be a first step, and the muscle (with the mastoid part of splenius capitis) will be mobilised and everted as far down as C6.

French textbooks simplify a rather cumbrous nomenclature: they use our old term complexus for semispinalis capitis, and call longissimus capitis complexus minor. These two 'complexi' pass from neck to skull without forming any attachment to the first three cervical vertebræ. So, since the skull base projects back at an angle from the spine, these muscles bridge the angle and subtend a space. This space, which is divided from its fellows by the midline partition of ligamentum nuchæ, forms *one half* of the suboccipital space: each half is encroached on (1) by a major mass of fat; (2) by bellies of two posterior recti and two oblique muscles. Our three ramal objectives lie in the ipsilateral half space.

These objectives are the first posterior cervical ramus or suboccipital nerve, which is purely motor, save for an occasional sensory twig; the second, whose medial branch is the greater occipital; the third, whose medial branch is the third occipital. The greater and third occipitals are mainly but by no means entirely sensory.

A small downward extension of the exposure described below reveals the posterior ramus of C4. If, therefore, we expose the outer edge of the complexus mass, we can then find a path in front of it to all our main objectives. The *back* of both 'complexi' has already been uncovered at the upper end by the reflection of sternomastoid and splenius capitis; the outer edge remains concealed by slips of levator scapulæ and splenius cervicis—both of which reach the transverse process of atlas.

The precomplexal fat.—With these slips turned down and back the edge of the complexus mass appears, and we are free to pass in front of it and enter the potential space. This space is filled with a major bulk of soft fat that bathes the second and third posterior rami together with a rich venous suboccipital plexus. A separate and minor fat deposit that lies on a plane deep to the small muscles of the suboccipital triangle and therefore next the vertebræ, guides us to the sub-occipital nerve.

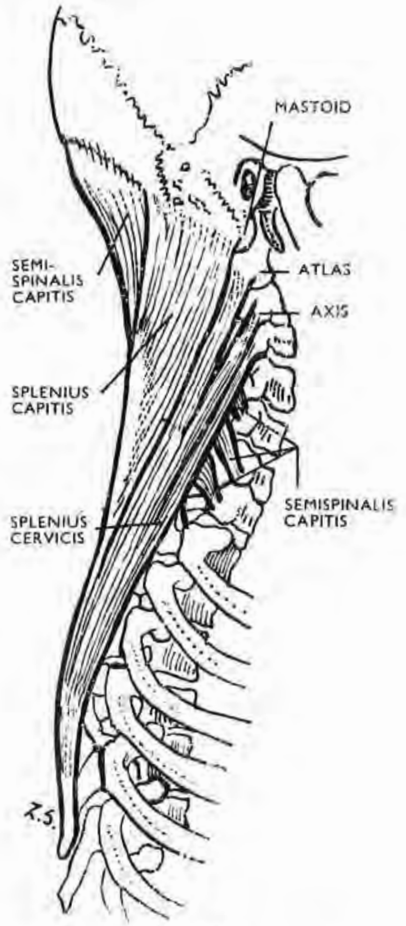


Fig. 51

Two covering muscles—sternomastoid and levator scapulæ—have been removed showing the underlying set.

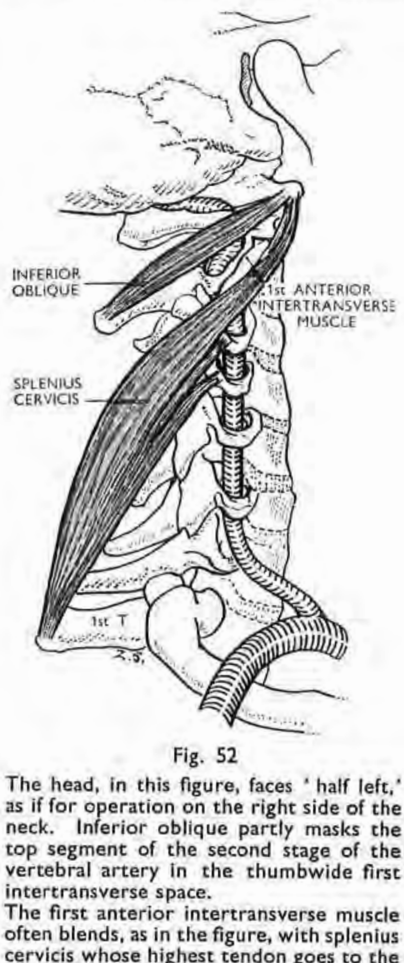


Fig. 52

The head, in this figure, faces 'half left,' as if for operation on the right side of the neck. Inferior oblique partly masks the top segment of the second stage of the vertebral artery in the thumbwide first intertransverse space.

The first anterior intertransverse muscle often blends, as in the figure, with splenius cervicis whose highest tendon goes to the tip of the transverse process of atlas where it is covered by the highest tendon of levator scapulæ. Failure to recall this superposition of a nearly finger-thick and well-defined levator origin upon a thin and flattened splenius tendon explains why the surgeon, after easily surrounding and dividing the levator piece, so often thinks he has merely cut through part of it. So, for complete clearance of the first intertransverse space, divide levator and spenial attachments to the transverse process of atlas ; disrupt the anterior intertransverse muscle.

The entry to an intertransverse space.—The slips or fascicles of levator scapulæ and splenius cervicis, together with those of longissimus cervicis and scalenus medius (which all go to posterior tubercles of transverse processes) cover the outer edge of the two 'complexi'; they also mask the entry to upper intertransverse spaces. The *names* of the fascicles, however, matter less than the ease of cutting them at their attachment to transverse-process tubercles. After they are cut, access can be got by divulsing intertransverse muscles. (This paragraph merely repeats and extends the procedure used in exposing the vertebral artery between axis and atlas, p. 64.)

Thus it is clear that if *lower* parts of splenius and the 'complexi'—supplied by C4 and C5—are also concerned in spasm, we must (since a cervical nerve corresponds numerically with the vertebra next below) open the *third and the fourth* intertransverse spaces to reach these rami. The third space will need for that a small retraction of the *anterior* ramus of C3; and the fourth and fifth the additional and less easy displacements of the corresponding rami of C4 and C5.

FALLACIOUS GUIDES.—It has long been the custom of text-books to repeat that we should begin by finding the thick posterior ramus of C2, and should then proceed to use it for locating the less thick rami of C1 and C3 by tracing the connecting loops that link them with C2.

Unfortunately, these connecting loops are hard to find. That to C1 may pass either in front of, or through, or behind the belly of inferior oblique, while the connection with the posterior ramus of C3 is equally elusive. Both loops break when strenuously sought.

FIXED LANDMARKS.—These posterior rami can be found *separately* by relating each to a fixed landmark.

The posterior ramus of C1 (the suboccipital nerve).—Find the belly of inferior oblique lying on the axis lamina deep to the complexus mass; it goes from the axis spine to the end of the transverse process of atlas Isolate it cleanly and divide its lateral attachment. Then, when the belly is turned *in* towards the spine of axis, the eye catches a gleam of fat among so many muscles—a pool no larger than a finger-tip, confined by membrane to the atlas arch. This fat is the required shield for the sub-occipital nerve and its companion vessels in a zone of restless concertina movement. It lies *deep* to where inferior oblique and rectus capitis major diverge as they go outwards from the axis spine (Fig. 50).

A very gentle dissection of this minor pool of fat with the lesser ball of a dental burnisher reveals a spray of motor nerves that stem from the posterior ramus of C1 and pass (1) to both obliques; (2) to the posterior recti; (3) to complexus. These nerves mingle with large, delicate veins (connected with the vertebræ), which then join the corresponding half of the sub-occipital venous plexus that lies in the *major* bulk of precomplexal fat.[1]

The posterior ramus of C2 parts from the anterior ramus one fingerbreadth medial to the tip of the second cervical transverse process. After this it floats in the major mass of fat in front of the 'complexi' and seems surprisingly redundant till we recall the free excursion of the head. Apart from size there is a sharp (and useful) difference between the anterior and posterior ramus of C2; the posterior ramus is lax, mobile, and therefore fugitive; the anterior is rigidly fixed to the top segment of the second stage of the vertebral artery. We can thus use the steadfast, easily located anterior ramus to guide us to its large and more elusive fellow.

Find first the top segment of the second 'vertebral' stage (p. 58). Find on the outer face of this segment the part of the anterior ramus of C2 that hugs the artery. This part of the ramus often lies as much as a $\frac{1}{2}$ in. above the transversarial foramen of axis; it is always tightly bound to the vessel by a tough, thin sheath of fascia, and may be squeezed so flat as to seem absent—unless the sheath is opened, when it swells surprisingly. Do not, however, liberate the anterior ramus and so lose the advantage of its fixation.

Then, having found the arterial segment of the anterior ramus, make the ball of the dental burnisher follow its lower edge *inwards* across the back of the artery; the ball leaves the artery, dips forward and strikes bone near the atlanto-axial joint. Keep touch with bone and continue to move the ball inward *in the same transverse plane* through a mere $\frac{1}{4}$ in.—the fore-and-aft thickness of a little finger-tip. The ball will then engage the angle where the two rami part. Turn the ball in and down, and hook backward the lax posterior ramus. Divide it on the burnisher, controlling

[1] *Another means of finding the suboccipital nerve.*—Supposing that the minor pool were dissipated through rupture of its membrane by surgical activity, then—on the *right* side of the neck—put the pulp of the *left* index finger, pointing headwards, on the back of the tip of the transverse process of atlas. The pulp of the middle finger, thrust in alongside index towards the atlas arch, will touch the spot. (On the left side use the two corresponding fingers of the right hand.)

first the large companion offset from the vertebral artery. (The ball of the burnisher is a safeguard; for if the instrument should stray too far inwards while the patient's head is turned away from the surgeon, the ball precludes the risk of breaking the thin posterior atlanto-axial membrane and entering the spinal canal. Used properly, however, the ball will always have the bulwark of the lateral atlanto-axial joint in front of it.)

Beyond the point of section the lax posterior ramus divides into two branches: (1) a slender lateral branch which is purely motor; and (2) a stout medial branch, the greater occipital nerve, which is chiefly sensory though giving strong motor twigs.

The posterior ramus of C3 is found when the back part of the space between the second and the third transverse process has been opened by dividing tendinous fascicles attached to the tubercle of the second process, and cleared by removing the second posterior intertransverse muscle. Proceed inwards till you see the *back* of the column formed by articular apophyses of C2 and C3. The third posterior or cervical ramus winds backwards against the posterolateral surface of the *upper* articular apophysis of C3. (Soulié, in Poirier and Charpy's *Traité d'Anatomie Humaine*, 2^e^ Edn., 1901, T. iii, fasc. 3, p. 887, gives the upper apophyseal relation to the posterior ramus of C3, but he makes the ramus lie in a *rainure*, a narrow groove or fissure, whereas it lies, as Wood Jones shows, on a smooth surface that is concave from above down; and so does the posterior ramus of C4. On C5 the smooth surface may be replaced by a groove—a true *rainure*—and be absent on C6 and C7 (*Journal of Anatomy and Physiology*, 1912, **46**, 41)).

A posterior ramus is easily displaced while opening an intertransverse space; leaving its articular apophysis, it may lie like a bucket handle near one or other transverse process—a fact worth remembering before search becomes fevered. It is also worth remembering that though medial branches of cervical dorsal rami may send twigs to reach skin, they, like the lateral branches, always supply muscle. It is therefore important to resect both branches in order to procure sufficient nuchal palsy. The books, however, show reluctance in describing *where* exactly the dorsal ramus divides.

One of my former teachers, H. M. Johnston, found that in the cervical region the medial branches from the dorsal rami of the lower six cervical nerves (C3 to C8) are separated from the corresponding lateral branches by distinct ligamentous bands, each of which extends from the capsule surrounding the articular apophysis to the transverse process of the succeeding vertebra, *e.g.*, from the joint between C2 and C3 down and outwards to the transverse process of C3 (*Journal of Anatomy and Physiology*, 1909, **43**, 81). It follows therefore that a very proximal division of the dorsal ramus occurs in the neck, and that a very proximal neurectomy is needed to include the lateral with the medial branch.

So, if you find a dorsal nerve winding round the posterolateral face of a columnar articular process, trace it proximally—out and forwards—to ensure complete resection of the two branches.

The accessory nerve on the side opposite the ramal exposure.—Section of this nerve is best made in the way advised by Aird, through an incision in the skin-fold of the neck, 3 cm. (two fingerbreadths) below and behind the angle and lower border of the mandible. (The *other* accessory has been exposed already, with the rami.) After dividing the investing layer of deep fascia the accessory is found coursing obliquely down and back on the prevertebral sheet, often one or two fingerbreadths below the tip of the transverse process of atlas but seldom crossing it. The nerve lies either superficial or deep to the internal jugular vein, which it sometimes perforates.

It will, however, be remembered that the sternomastoid also receives fibres that usually come from the anterior ramus of C3 but sometimes from that of C2, or from both. (See footnote on p. 81.) These fibres often join with the accessory fibres through a loop-hole in the muscle that is best seen when the upper end of sternomastoid is detached and turned outward from the skull (Fig. 53).

The accessory nerve either (1) passes deep to the whole potential triceps (or rarely, quadriceps) arrangement of sternomastoid ; or (2) perforates the almost vertical fibres of the deep, cleidomastoid head of the muscle, and is covered by the two (or three) more oblique and superficial heads—the sternomastoid and cleido-occipital (Fig. 53), plus if it is present, the rare and slender sterno-occipital head. According to Farabeuf, the accessory never pierces a superficial head, nor does it insert itself *directly* between the single deep head and the two (or three) superficial heads, but only intervenes after passing through the deep head.

The need for treating the large functional element in spasmodic torticollis suggests the value of a placid interval obtainable by paralysing relevant nerves for a mere few months, instead of permanently, by resection. The interval can be got after crushing the nerves in continuity.

I learnt this useful thing the hard way in 1930 when in a moment of unwise compunction I elected to crush limb nerves in an *organic*

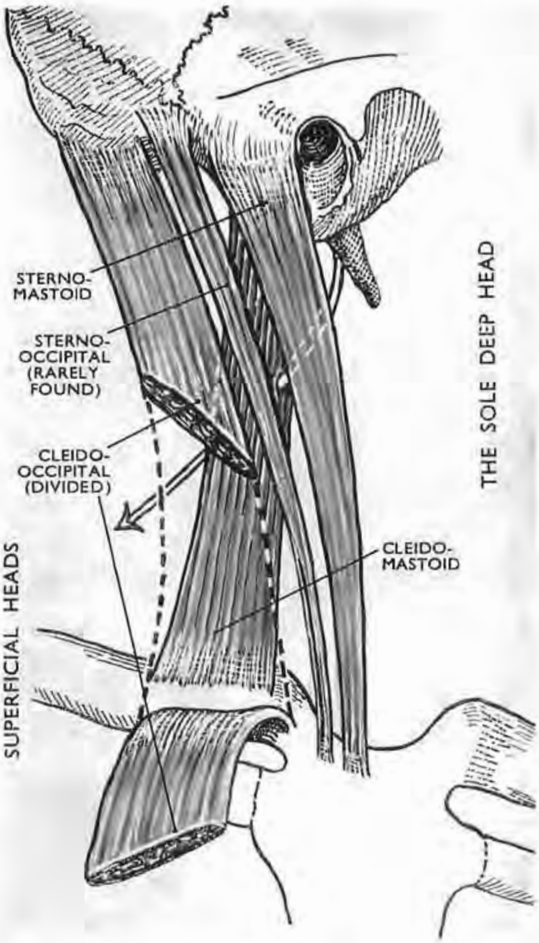


Fig. 53

The sternocleido (occipito) mastoid (after Maubrac and Charpy)

This muscle is commonly a triceps, the separation of whose heads varies in degree. It becomes quadriceps (as seen above) only when the rare sterno-occipital head is manifest. In either type all heads but one are superficial. The sole deep head is the cleidomastoid. The accessory nerve may lie deep to the deep head, or may pierce it—like the plastic arrow in the figure.

case with spastic paraplegia, and three months later was obliged to resect them when the full spasm returned.

Recently G. D. H. Shawe (*British Journal of Surgery*, 1955, **42**,

474) has published work on the rabbit, which is perhaps relevant to my clinical reverse. He finds that on the average each axon central to a crushed point in a motor nerve gives three branches by 20 days. The level at which branching begins is about 6 mm. above the injury. Below the crush the number of fibres reached its maximum at 50 days. By 100 days many branches had disappeared, but the fibre content of the nerve was about 50 per cent. higher than normal and remained so for as long as it was studied (225 days). Curiously, if a nerve had been *severed* and sutured immediately, branching was of greater extent than after crushing, while the distal portion of the nerve contained *twice* the normal number of fibres even 200 days after the lesion.

Fig. 54

Showing how the biceps tendon dips into the antecubital V

Beside and medial to biceps is the Fiolle and Delmas incision ; it is designed solely for neurovascular structures. In order to expose these structures *in company with humerus* (and elbow joint) the upper part of our incision lies *lateral* to biceps (see Fig. 24).

THE DISTAL PART OF THE HUMERUS EXPOSED IN CONTINUITY WITH ANTECUBITAL STRUCTURES

What follows is a mere variant of the innocuous and beautiful exposure described by Fiolle and Delmas, which brings to light the least accessible part of the ulnar vessels and median nerve, and I shall first indicate *their* method. A skin incision medial to the biceps goes down beside the tendon, and then obliquely out to the junction of the lower and middle thirds of radius ; nothing is cut except skin, superficial fascia and veins. The deep fascia is carefully opened.

In this region the biceps tendon dips into the wide part of a muscular V (Fig. 54), whose medial limb is the pronator teres flanked by flexor muscles ; the lateral limb of the V is the brachioradialis with two other bellies that form a wad which can be grasped and moved below the elbow (p. 94). After dividing the tight surrounding sleeve of fascia the two limbs of the V part easily ; if then the forearm is flexed and placed in full pronation, the muscles covering deep-lying 'difficult' portions of ulnar vessels and median nerve relax and give wide access to every antecubital structure.

Remembering this method we combine exposure of the humerus with easy exploration of the fossa, although the upper part of our incision is on the *outer* side of biceps and therefore opposite to that of Fiolle and Delmas.

THE OPERATION

With the patient's elbow extended and the forearm supine continue the lateral incision for the shaft of humerus (p. 34) beyond the antecubital fossa, curving it in to end two-thirds of the way down the ulna (Fig. 55, A). When we reflect the skin covering the tendon of biceps we shall find the stout band of bicipital fascia (lacertus fibrosus) that forms a sort of retinaculum over the median nerve and distal end of the brachial artery. Dividing the band we then proceed to rip the sleeve of fascia that constricts the antecubital V and cramps its limbs together. But once these limbs are free, a finger, dipping in between, can easily disrupt the loose connecting tissues which "break and disappear like soap-suds."

Find the origins of the radial and ulnar arteries close to the inner side of the biceps tendon. Look for the median nerve still farther in beyond them. Mobilise these neurovascular structures by gently opening Mayo scissors close alongside; then put the forearm into full pronation and draw the limbs of the V apart. The whole complexion of the wound is suddenly transformed: a beggarly view becomes a wide prospect with every structure fortunately placed (Fig. 55, B).

The interosseous artery and its anterior interosseous branch.—These wide and deeply situated branches lie behind a double screen: the parent ulnar trunk lies on their origin, and it is masked in turn by the main radial vessels. These last are mobilised by cutting twigs that moor them to the muscles. A fan-like set (called 'radial recurrent' from *upper* twigs that loop towards the elbow) is found at once: a finger moving down the outer face of biceps tendon will catch the loop and let us cut the fan. Then forceps on the severed stem rotate the radial artery and veins away towards the ulnar shaft, uncovering the ulnar artery and drawing it aside by gentle force transmitted through the parent brachial trunk (Fig. 55, C).

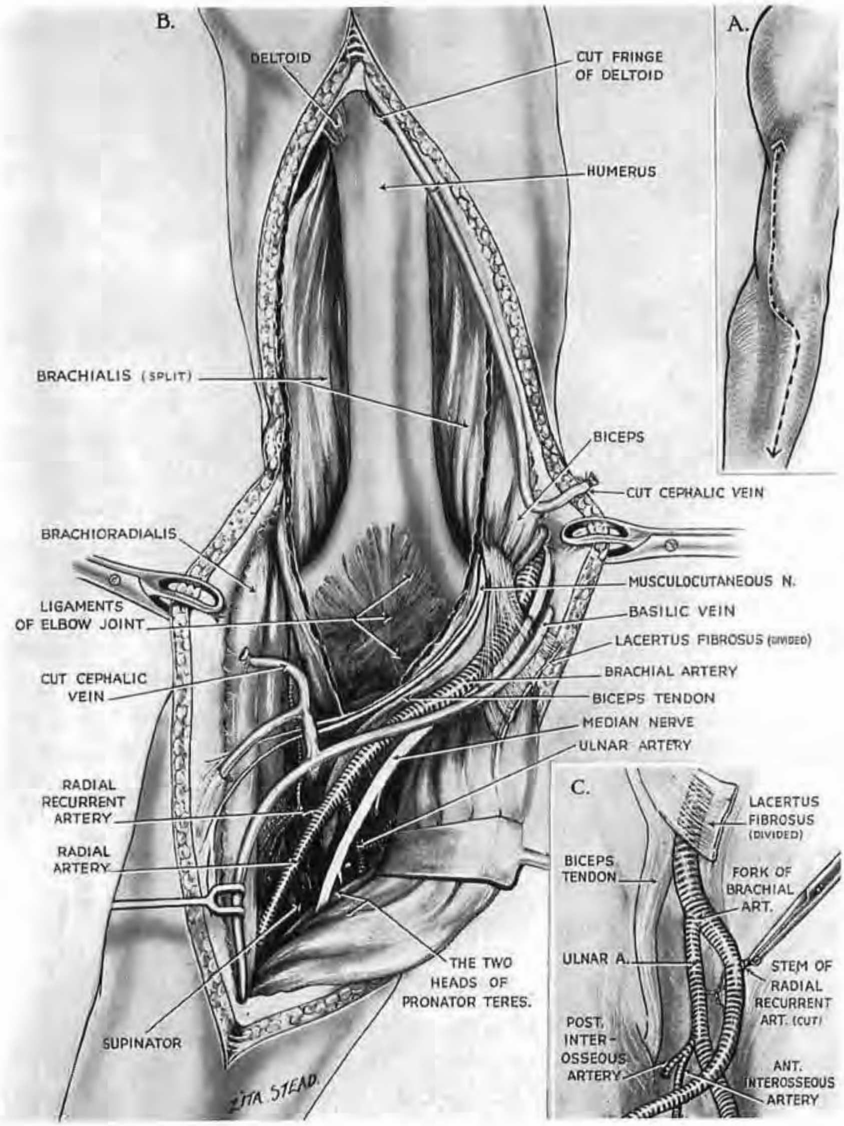


Fig. 55

Extension of distal humeral exposure to the antecubital fossa

A. The whole incision. This is made with the limb supine. (See legend to Fig. 24.) B. The exposure. The forearm is now *pronated*, relaxing the antecubital V so that retraction shows the deep part of the ulnar artery. C. Division of the stem of the vascular fan formed by the so-called 'radial recurrent' provides a handle for rotation and displacement of the brachial fork towards the ulnar shaft—a movement which uncovers interosseous vessels.

This simple movement inwards of radial and ulnar affords a full exposure of our interosseous objectives and yields a thorough view of veins and arteries that ramify within the fossa—a place whose depths should cease to give excuse for hæmostatic rooting.

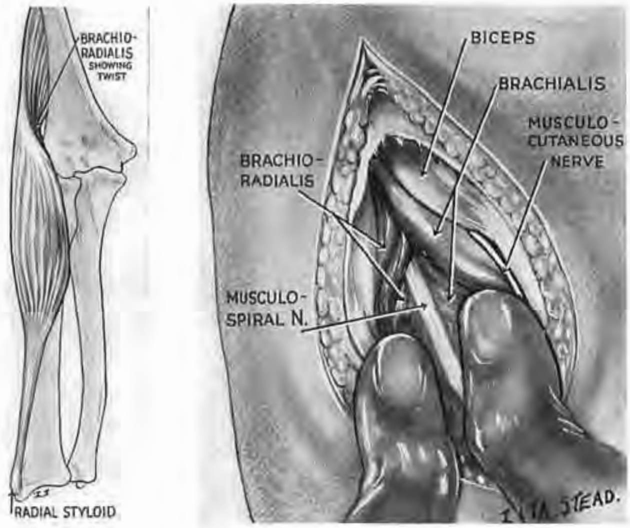


Fig. 56

Finding the distal end of the musculospiral (radial) nerve

A thumb on each muscle opens the spiral plane of cleavage between brachioradialis and brachialis as one would open a book. Inset, The twist of brachioradialis which is moulded to the tapering brachialis.

Finding the distal end of the musculospiral (or radial) trunk.—There is sometimes delay in finding this part of the nerve. It lies here in a peculiar *spiral* plane of cleavage between brachioradialis on the lateral side and brachialis on the medial; for where these bellies touch the brachialis tapers while its fellow twists. So, after dividing deep fascia do not use a knife to reach the nerve; instead place well-gloved thumbs, lengthwise and parallel, one on each belly, and open the plane—like a book on your knee. The nerve marks the place (Fig. 56).

THE FRONT OF THE FOREARM

ANATOMY

We shall consider the muscles first; their arrangement in respect of each other, and sometimes their intimate constitution, are clues to several exposures. So we shall make it easy for the mind to build the part like a model—and then take it to bits.

Fig. 57

Recognition of the mobile wad of three muscles below the lateral epicondyle of humerus

The muscles, from before back, are brachioradialis, long and short radial extensors. This wad can be moved *across* the part of radius clothed by supinator, *against* the neighbouring muscles. The anterior and posterior edges of the wad, defined in this way, serve as guides for making incisions and discovering planes of cleavage (see Figs. 65 and 77, A).

The mobile wad of three.—Let us first exclude three muscles we have met already (p. 90), which can be grasped with finger and thumb, and moved to and fro as a mobile wad just below the lateral epicondyle of the humerus (Fig. 57). They are, from before back, brachioradialis, and the long and short radial extensors of the wrist. These mobile bellies flank the radius on the outer side and ride at anchor on a fan-shaped leash of vessels from the radial trunks—a leash we must divide before we can retract the muscles outwards or the trunks in (pp. 91 and 99).

The rest.—The remaining muscles are arranged as three groups: (1) superficial; (2) intermediate; (3) deep.

The *superficial group* consists of four muscles, remembered by placing the *ball* of the opposite thumb on the front of the medial epicondyle, letting the thumb and *three* fingers point along the supine forearm (Fig. 58). The thumb lies obliquely and marks the course of the oblique pronator teres; the index finger touches the tendon of flexor carpi radialis close by the radial pulse; the middle finger takes the place of a frequent absentee—palmaris longus; the ring finger covers the last muscle of the group, flexor carpi ulnaris. (The little finger plays no part

Fig. 58

A manual mnemonic for superficial muscles on the front of the forearm

Place the opposite hand on the front of the forearm as in the figure, with the thenar eminence covering the medial epicondyle. Thumb and fingers indicate the lie of superficial muscles ; the little finger plays no part. Note how pronator makes a bridge across the forearm.

in these manual mnemonics which we shall do well to practise first on our own forearms.)

The *intermediate group* has one muscle only—flexor digitorum sublimis—but a muscle of some complexity, whose close and peculiar relations with the median nerve are of practical importance. Its tendons go behind the transverse carpal ligament as if they had 'formed two deep'—a fact which betokens the two-layered arrangement of the fleshy parts. The *superficial portion* of sublimis belonging to the front-rank tendons—for ring and middle finger—is a thin sheet that slants across from humerus to radius bridging the interval between the bones of the forearm (Fig. 59). The median nerve and the deep, 'difficult' portions of the ulnar vessels diverge as they leave the antecubital fossa and pass beneath this bridge, whose arch—which gives them entry—has varying relations with the bridging belly of pronator teres. Pronator either overspreads the arch of the sublimis (forming a double-layered span), or else sublimis lies more distally (so that the spans are separated by a gap)—a point of some importance in looking for the median nerve (p. 106).

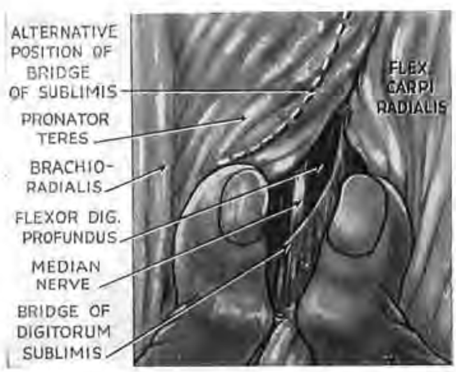


Fig. 59

The superficial part of sublimis

This part gives rise to the two front-rank tendons (for ring and middle finger). It forms a bridge whose oblique entrance may have a high or low level in the forearm and thus be either deep or distal to pronator teres. The median nerve therefore runs either under a two-layered arch (formed by pronator plus sublimis), or else must cross a gap between two separate spans. (See inset where flexor carpi radialis has been retracted to show the median in the gap. The dotted line indicates the proximal variety of sublimis arch.)

The *deep part of sublimis* is trigastric (Fig. 60); the two distal bellies correspond to the rear-rank tendons—for index and little

Fig. 60

The deep part of sublimis (after Poirier)

The two distal bellies of the trigastric portion give tendons to little finger and index—the rear-rank tendons which enter the wrist behind those of the other two fingers. The median nerve is bound in satellite relation to the radial side of the deep part of sublimis.

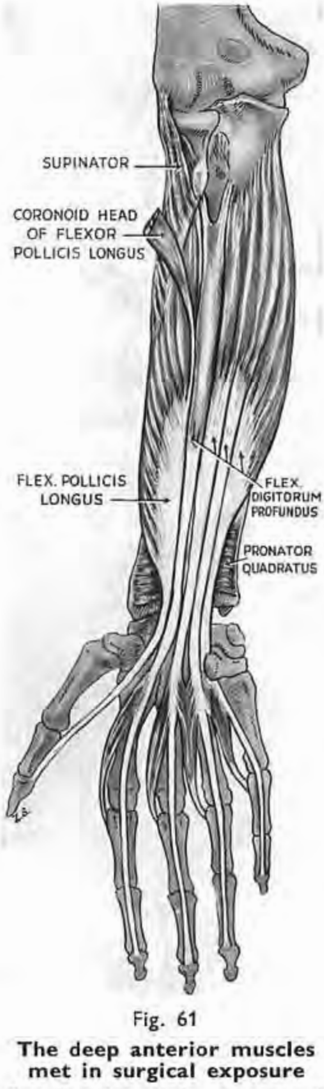


Fig. 61

The deep anterior muscles met in surgical exposure

One lies lengthwise along each bone. One joins the proximal ends of the bones, one the distal. (The index tendon is the only tendon of profundus that separates in the forearm; the others are conjoined till they reach the palm.)

finger; the proximal belly springs from the common origin on the medial epicondyle of the humerus.

The satellite median.—After leaving the antecubital space the median nerve becomes a satellite of the deep part of sublimis, lying first to the radial side of the proximal belly; then to the radial side of the intermediate tendon which is sometimes an obvious glistening thing, but often dull and cord-like enough to simulate the nerve itself. Below this level, fascia binds the median in a lateral groove between the front- and rear-rank tendons that go respectively to middle and index fingers. The nerve, therefore, stays with sublimis if we separate that muscle from profundus. We shall see (on p. 109) how to find the median near the wrist.

Loose tissue joins the single, intermediate, sublimis to the deep group, forming a plane of facile cleavage that is used with great advantage by McConnell (p. 107).

The *deep anterior group* consists of four muscles (Fig. 61): one lies along the length of each bone—the flexor of the thumb upon the radius, profundus digitorum on the ulna. The other muscles cross *between* the bones—the supinator near the elbow, the flat quadratus near the wrist. (I know I contravene morphology by classing supinator with anterior muscles, but here we meet the supinator first in *front*; and this book deals in practice.) Note that the tendons of profundus digitorum—unlike the tendons of sublimis—lie in a single rank of four abreast.

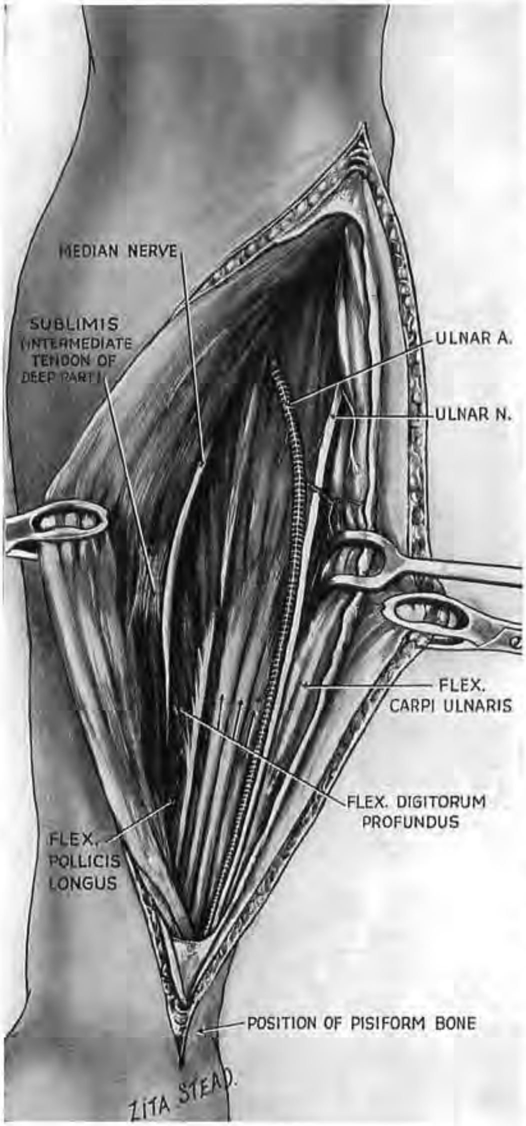


Fig. 62
The ulnar neurovascular bundle belongs to the *deep* layer of muscles. Note how the bundle splits proximally. The median nerve sticks to sublimis.

The *ulnar nerve* comes to the front of forearm from behind the elbow. It is thus natural to find it fastened to a member of the *deep* group of forearm muscles—flexor digitorum profundus, a muscle one of whose origins wraps widely round the upper and inner two-thirds of the ulnar bone.

The *ulnar vessels* join the nerve at a sharp angle and then go down its radial side, forming with it a neurovascular bundle (Fig. 62) partitioned from the inner flank of forearm by the tendon of flexor carpi ulnaris. We have already noticed these vessels leaving the antecubital fossa (p. 96); we now see they do so by passing between the deep and intermediate groups of muscle.

The *radial artery* begins at the medial side of the biceps tendon; and so its oblique proximal part becomes a satellite of the oblique pronator teres which also has a medial origin: the artery is bound by fascia to the muscle,[1] though books omit the fact and harp instead on the relation here of brachioradialis. That is why one sees despairing *outward* hunts in the proximal third of forearm to find a vessel which comes from the inner side. This artery, with its companion veins, is dangerously near the surface and may be slit in opening the fascial sleeve of swollen limbs.

The *tendon of biceps* is a major landmark, a vertical partition which divides the proximal portion of the antecubital V into a 'dangerous' area on the medial side, a 'safe' one on the lateral—provided of course the knife stays close to the tendon and does not wander out to threaten the end of the musculospiral nerve, the radial of Basle nomenclature.

The tendon leads through loose fat to the tuberosity of radius, a part of which is covered by the *bicipital bursa*—whose aid we shall enlist.

The radial leash, called "recurrent."—Crossing the 'safe' lateral area of the antecubital fossa is a group of vessels called recurrent radial; only the most proximal deserve the name by running up the limb; the other members are important muscular twigs which spread out fanwise to the mobile wad of bellies that flank the radius (p. 91). The wad therefore is moored to the radial trunks by a fan-like vascular leash whose vessels—which rib the fan (Fig. 63)—seldom lie in a single plane but diverge in a set of layers two or three deep; *all* these must be divided to free the tethered muscles—unless we cut the stem from which they spread. A finger moving distally along the outer face of biceps tendon will feel the leash (which lies invisible in fat) and hook it up—a welcome guide in featureless surroundings.

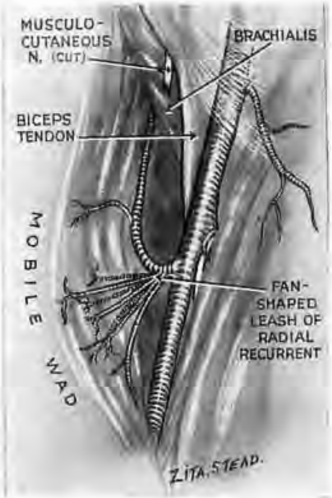


Fig. 63

The fan-like leash of vessels called 'radial recurrent'

(The veins are not shown.) Only the proximal rib of the fan is recurrent. The ribs are in several layers—two, three, or four deep. They are muscular branches which tie the mobile wad to the radial vessels.

The branch once called the radial branch of musculospiral, alias (in B.N.A.) the superficial terminal branch of radial, and now (in fitful text-books) lumped with the parent stem as 'radial'[1]—this branch, by any name you choose, clings to the mobile wad of muscles, the hinder one of which it may supply.[2] The satellite relation of the nerve and wad involves reciprocal divorce (and therefore easy severance) from close-adjoining radial vessels, which go for their part with pronator teres and then with flexor longus pollicis. (A way of finding the distal end of the parent trunk is described on p. 93.)

The *medial cutaneous nerve* of the forearm lies to the ulnar side of any elective incision we shall make on the front of the limb—excepting McConnell's (p. 107).

EXPOSURE OF THE WHOLE SHAFT OF RADIUS FROM IN FRONT WITH EXTENSIONS TO MEDIAN AND ULNAR NERVES

We have thus built a rough but working model of the front of forearm. Let us now take this apart sufficiently to see the whole length of radius.

First, we must still further mobilise the wad of three mobile muscles (brachioradialis, long and short radial wrist-extensors) so that we can draw them well away from the lateral face of radial shaft. We shall therefore use an incision that follows these muscles

[1] Impatient persons (like the *Queen of Hearts*) wish off the heads of *all* who are responsible. But *Alice* (duly coached and kindlier) might put our three nomenclatures in one portmanteau and call the slithy nerve the *radial branch of musculoradial.* (Its deeper fellow is, of course, the *muscular.*)

[2] C. R. Salsbury, *British Journal of Surgery*, 1938, **26**, 95.

right into the *arm*. Then, after opening deep fascia, we shall cut the fan-shaped vascular leash—the so-called radial recurrent—which holds them tethered to the main radial trunk. Lastly, we undo the supinator, whose *deep* fibres come across from ulna to grasp from behind—like fingers of a hand—the upper third of radial shaft. A second set of supinator fibres slopes down over these.

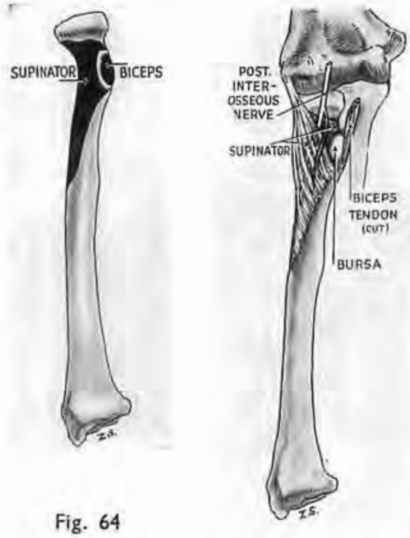


Fig. 64

Anatomical relationships at the upper part of the radius. The white crescent between the two black areas of attachment marks the site of the bicipital bursa and shows how it lies in a bay formed by the supinator edge. The surgeon is guided to the bursa —and thus to the edge of the supinator —by the outer face of the biceps tendon (see insets to Figs. 67 and 68).

Fig. 65

Incision for anterior exposure of the radius

The knife follows the front edge of the upper part of the mobile wad (brachio-radialis, long and short radial wrist extensors), and then proceeds as in this figure.

The *posterior interosseous nerve* (deep terminal branch of radial, B.N.A.) penetrates the anterolateral face of the supinator muscle, and separates its two layers; the deeper layer fends the nerve from radius. The part of supinator edge that skirts the tuberosity of radius curves also round a bursa of the biceps, which lies next bone and lubricates the tendon (Figs. 64 and 67). At first loose fat swamps everything; but once we find and cut the fan-shaped leash the outer face of biceps tendon leads us to the bursa, which we divide to reach the tuberosity, thus leaving the rugine a place to come in contact with the bone. Then, starting at the *edge* of supinator, we find the muscle easy to detach.

THE OPERATION

Incision.—First, with the limb supine, feel out the mobile wad of three muscles and incise as in Fig. 65. The incision goes up a

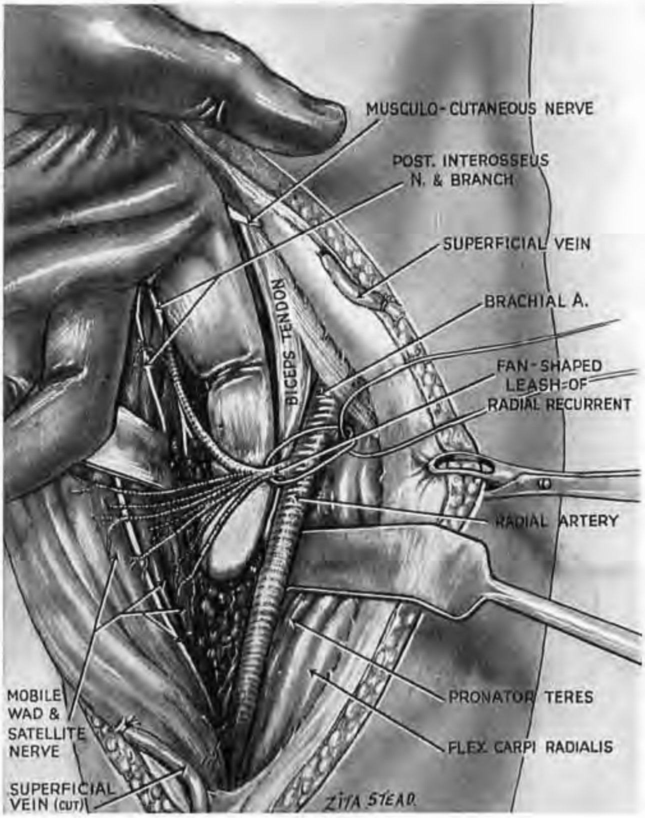


Fig. 66

Finding the fan-like leash

A finger slid lengthwise down the outer side of the biceps tendon feels the resistant loop of the recurrent proximal vessels. Be sure to catch up *all* the layers of the fan—two, three, or four—unless, as in the figure, you tie and cut instead the short single stem of the fan. Note that the radial branch of musculospiral (=superficial terminal branch of radial) is bound in satellite relation to the mobile wad.

handbreadth into the arm, keeping a fingerbreadth lateral to the edge of biceps (see p. 34); below, it reaches to the radial styloid. Divide and tie the large superficial vein that crosses the mid-third of radius, and may continue thence as the cephalic.

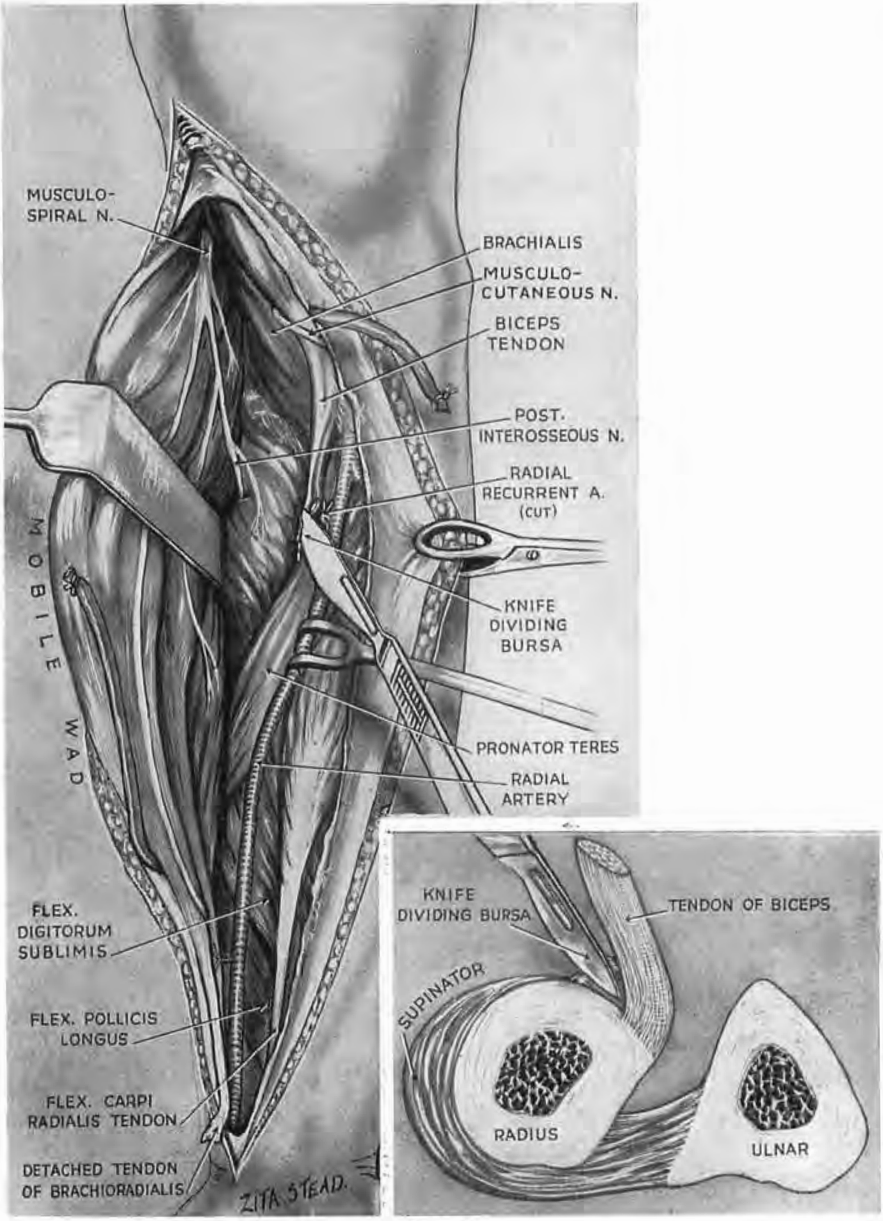


Fig. 67

The fan-like leash has been cut ; the mobile wad is free for lateral retraction. The knife, with the flat of its blade touching the ' safe ' outer face of biceps tendon, cuts through loose fat ; it then cuts through the bicipital bursa to strike the tuberosity of radius at the edge of the supinator insertion (see inset).

In this figure and the next, two points should be noted : (1) Fat which veils the front of supinator is omitted in order to show the muscle. (In spite of fat the *lining* of the bursal sac will glint when once the knife has cut into the cavity.) (2) The peculiar *curved* course of the cutaneous part of the musculocutaneous nerve is due to its retraction inwards with the skin. Note how the proximal part of the nerve appears at the junction of biceps tendon with biceps belly—a sure guide to its discovery.

The deep guide.—First expose the biceps tendon by dividing deep fascia on its lateral side. Go on dividing this fascia throughout the wound with *blunt-nosed scissors*, thus taking care of the radial vessels. Pass the finger down through the swamp of fat, along the outer side of the guiding tendon till you meet the resistance of the recurrent vascular loop (Fig. 66). Remember that this loop is only the proximal rib of a fan-like spread of vessels that lie in several layers. Hook up *all* the layers of the fan gently on the finger ; divide and tie them —or tie instead their narrow stem. Mobilise the wad of three long muscles which flanks the outer face of fore-

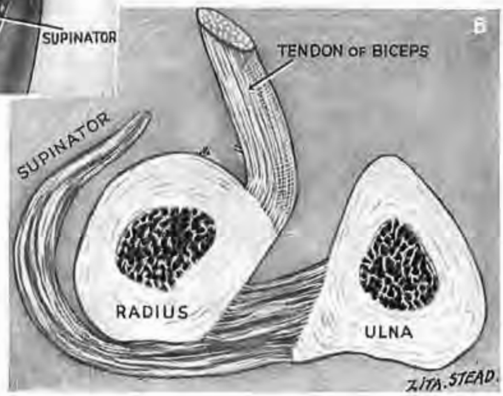


Fig. 68

The rugine working outwards from the site of the divided bursa begins to peel the grasp of supinator from the radial nerve. (In this figure the musculocutaneous nerve has no label.)

arm. Detach the flat tendon of brachioradialis from its hold on the base of the radial styloid. Flex the elbow through 90 degrees and retract the outer muscles widely to expose the supinator.

Return then to the biceps tendon. First make the tendon taut ; then, keeping the flat of the knife close to its outer face, cut down upon the bone. The knife divides bicipital bursa and strikes the tuberosity of radius, which lies embraced within a bay formed by the supinator edge (Fig. 67). From this strategic point the rugine peels the supinator muscle off the bone (Fig. 68). The muscle is turned outwards, sandwiching within its substance the posterior interosseous nerve (deep terminal branch of radial, B.N.A.).

Lastly, a vital part of the exposure : put the forearm into full pronation; the radius then will be revealed from end to end (Fig. 69).

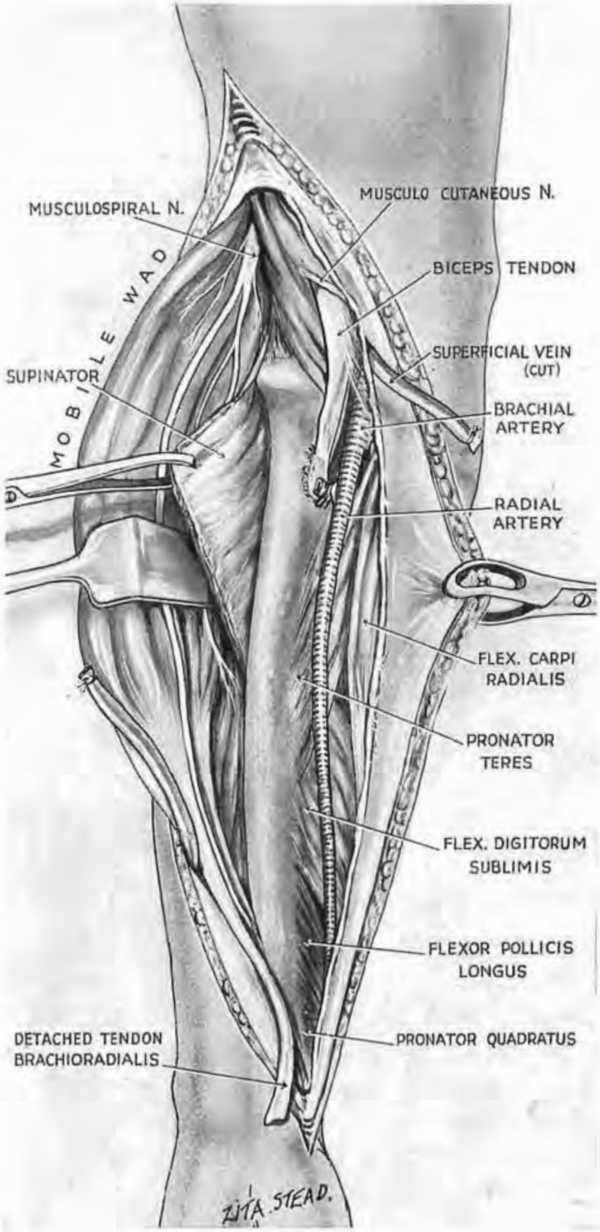


Fig. 69

The forearm remains supine till supinator is mobilised. Complete the exposure by putting the forearm into full pronation ; this will bring the bone to the surface, as in the figure.

UNREDUCED ANTERIOR LUXATIONS OF THE RADIAL HEAD.—These injuries are common where men fight with quarterstaffs. A forearm guards the skull from a descending blow whose force, breaking the ulna, drives the fragments on against the radius and thrusts its head in front. Then, if a closed reduction fails, the upper third of the complete exposure will serve for reposition or resection.

EXTENDING THE EXPOSURE OF RADIUS TO THE MEDIAN AND ULNAR NERVES.—Should we wish to extend the exposure, we have already seen how this is done for nerves and vessels of the antecubital region (p. 90): an attack begun there from the outer side of humerus was carried over to include them all. Let us now with equal ease spread our exposure of the radial shaft to embrace the median and ulnar nerves in the rest of the forearm—the distal two-thirds. If we begin our approach to the bone with a view to including these nerves, we shall of course make the forearm portion of the incision nearer the middle line than if radius were our sole objective; though in any forearm a *long* incision combined with trivial skin-reflection will bring us where we wish.

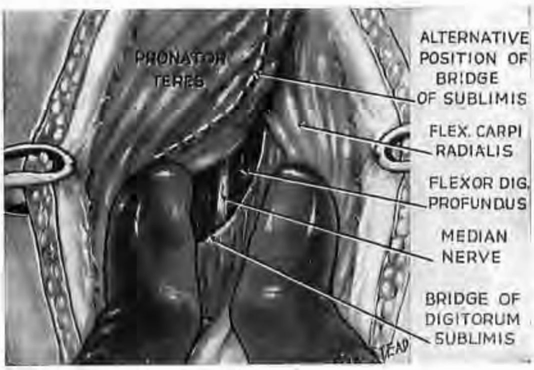


Fig. 70

Finding the median nerve distal to pronator teres.—Begin to separate the belly of pronator teres from that of flexor carpi radialis *where they diverge*. Use the thumbs back to back to move the muscles harmlessly apart. A short length of median *may* appear between pronator and sublimis, as in this figure. If not, you must split the thin superficial part of sublimis to see the nerve.

Exposing the median nerve from in front.—We must first find the plane of cleavage between pronator teres and flexor carpi radialis (between thumb and index of the manual mnemonic in Fig. 58). The *tendons* of these two muscles separate widely in the distal third of forearm, the place, of course, from which to prise apart the close-packed bellies—a thing most gently done with two thumbs back to back (Fig. 70). And now a short, flat-looking piece of median trunk will often show in the proximal part of the separation; it goes between the distal edge of pronator and the proximal edge of the bridge-like portion of sublimis. This glimpse of nerve (Fig. 70) is only possible when the sublimis bridge lies farther down the limb than the more superficial span of pronator teres—leaving a gap for the nerve to cross (p. 96). But when one span lies level with the other and covers it, there is no gap nor glimpse at all: there is instead (between our separating thumbs) an unrevealing face—the thin bridge of sublimis, whose grain we now must split to see the nerve. We know already we shall find it bound by a transparent fascia to the deep, trigastric part of that two-layered muscle.

The ulnar nerve exposed from in front.—If we wish to include the ulnar in the anterior approach, we must open the plane between sublimis and the deep layer, relaxing sublimis by flexing the hand. Drawing the muscle forwards, we shall then see that the space is closed on the ulnar side by a shining band of tendon, the flexor carpi ulnaris; beside it we shall find the ulnar nerve—bound, with the vessels, to deep flexor digitorum. Combined exposure of median and ulnar nerves is thus obtained as a by-product of the approach to radial shaft.

But, if our quarry in the forearm happens to be the distal two-thirds of median nerve, or the whole length of ulnar nerve—or both; or if a *medial* wound determines our direction, then we can make use of an exposure that has the "simple elegance" which Horace praised, joined (this time) with fidelity.

McCONNELL'S COMBINED EXPOSURE OF MEDIAN AND ULNAR NERVES IN THE FOREARM [1]

Lay the forearm supine. Incise skin only—from *radial* edge of pisiform to medial epicondyle (Fig. 71). Open deep fascia along the radial side of flexor carpi ulnaris tendon, working up from the distal end of the wound. The ulnar nerve and vessels are found at once and traced in a *proximal* direction to the sharp angle where they part company, the line of the vessels turning outwards from the straight course of the nerve (Fig. 71). It is then easy to find the friendly plane of cleavage between sublimis mass and flexor profundus (Fig. 72). The median nerve, we know, lies in a shallow groove upon sublimis, to the radial side of its deep trigastric portion. So, when the plane is opened up, nerve and sublimis move (and stay) in company.

It is often easy to mistake the intermediate tendon of the deep trigastric moiety for the median nerve (Fig. 71), and I shall

[1] A. A. McConnell, *Dublin Journal of Medical Science*, 1920, p. 90.

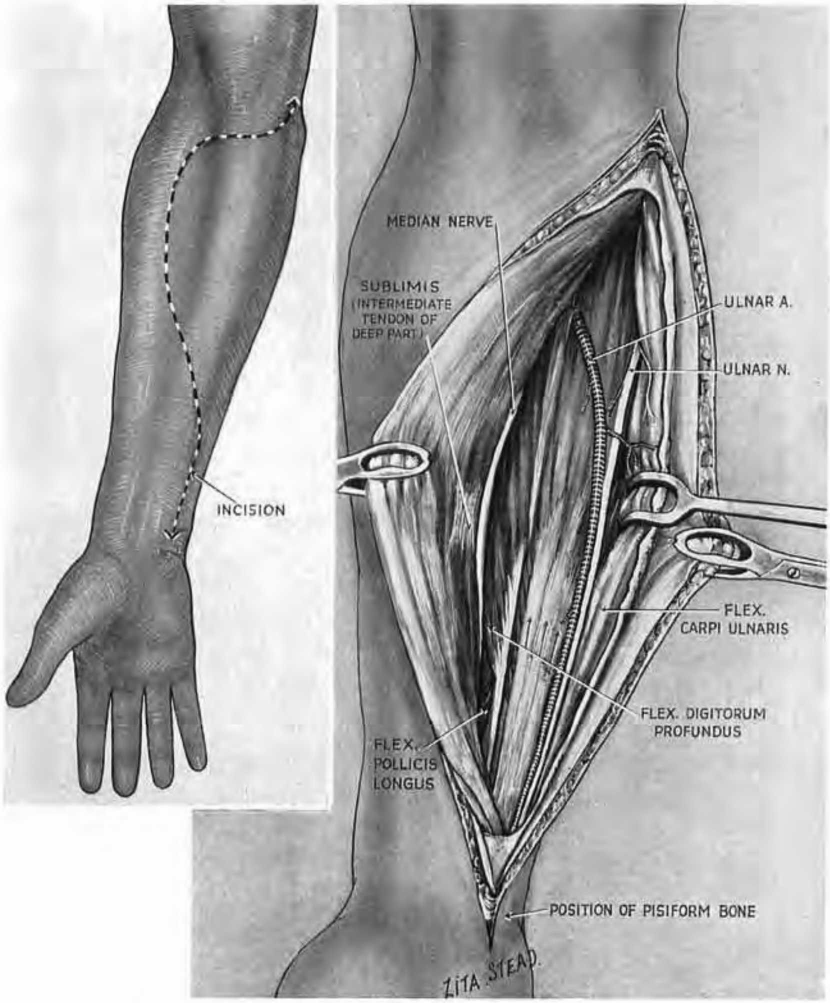


Fig. 71

McConnell's combined exposure of median nerve and ulnar neuro-vascular bundle

Incision runs from medial epicondyle to pisiform. (See legend to Fig. 24.) The plane between sublimis and profundus is opened up. Note how the median sticks to the sublimis ' roof ' ; the ulnar bundle sticks to the profundus ' floor.' Note, too, the intermediate tendon which sometimes simulates the median.

close with a double counsel : Do not too quickly rejoice at the first cord-like structure you may see—it is possibly a flexor tendon ; do not cut into the deep face of sublimis to look for the nerve ; you will only make a mess.

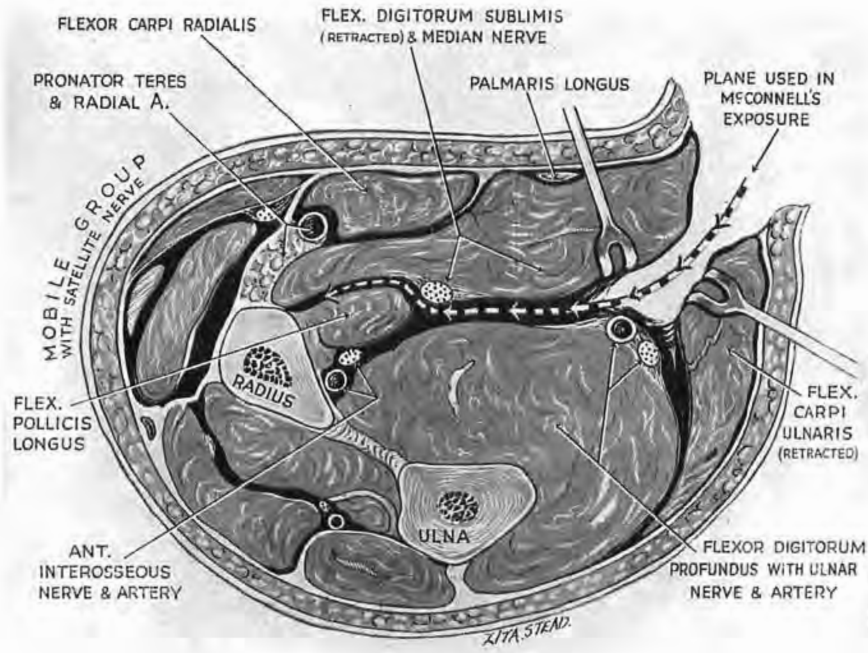


Fig. 72

Cross-section showing the plane of cleavage in McConnell's exposure

The plane is entered in front of flexor carpi ulnaris and in front of the ulnar bundle ; it lies between the intermediate layer of muscle (which consists only of sublimis) and the deep layer. The median nerve sticks to the ' roof ' ; the ulnar bundle to the ' floor.' (In practice entry is effected at a more distal and facile level—in front of the *tendon* of flexor carpi ulnaris.)

EXPOSURE OF THE MEDIAN NERVE ABOVE THE WRIST

The nerve just here is literally median, a fact to grasp if we would find it quickly ; for, despite tradition, palmaris longus is a mere decoy and has no value as a landmark. Out of 100 forearms, Tandler (that attractive person whose good work embraced both quick and dead) notes how the median lay behind or radial to palmaris tendon in 53 ; in 35, the nerve lay to its inner side ; in 12 he found no tendon. And I would add that when the median does lie close behind palmaris, the tendon often moves away once we retract deep fascia.

Other relations near the wrist.—The nerve—true satellite of the sublimis mass—keeps on one level and so comes near the surface at the wrist; for the limb tapers as the bellies shrink, leaving the nerve bare of flesh and flanked by tendon. But even here the inner edge of median (still faithful to sublimis) weds the groove between the front-rank middle finger tendon and its rear-rank index-finger file. The groove is deepened by the pointed fleshy tongues that coat these tendons till they reach the wrist; and up the groove a severed median may withdraw from sight.

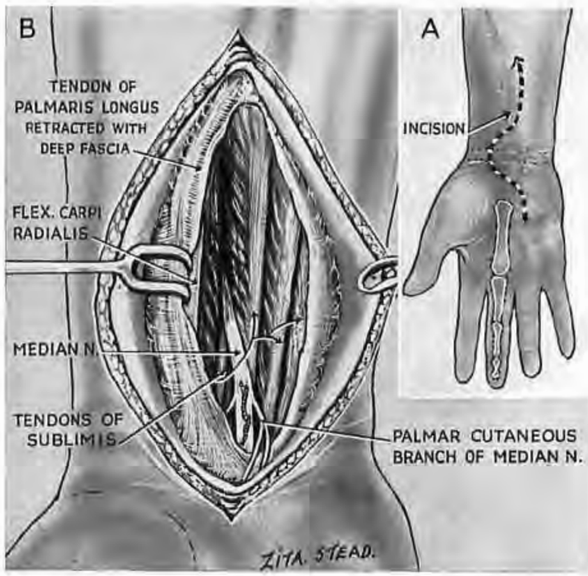


Fig. 73

Exposure of the median nerve close above the wrist

A. The axis-line incision reaching the distal 'bracelet.' B. The exposure. Palmaris longus is retracted with deep fascia. The *fixed* relation of the nerve is to the middle-finger tendon of sublimis, in front of which it winds

THE OPERATION

The axis line.—The certain guide (because the nerve is median) is the long axis of the middle metacarpal bone—produced, of course, into the forearm (Fig. 73). So make the knife continue that long axis up the limb. Begin incising at the distal 'bracelet' which marks the forearm skin, and end the cut at least four fingerbreadths above. Use this line, too, for opening the deep fascia; displace the chance obtrusion of palmaris tendon. The nerve is seen at once, marked often by a small meandering vessel.

Above, the median disappears beneath a pointed fleshy tongue of the sublimis ; below, and near the ' bracelets,' it gives a branch which overlies the parent trunk and goes to palmar skin. The main nerve leaves the wound beneath the bridge of transverse carpal ligament and, just before it vanishes from sight, lies on the *front* of the sublimis tendon for the middle finger (Fig. 73).

This exposure may, of course, continue, or be continued into, the *anterior* approach to median and ulnar nerves described on page 107.

THE BACK OF THE FOREARM

The arrangement of parts here is very simple.

The *mobile wad* is the same wad of three muscles we know already :—extensors (radial) long and short, brachioradialis—a boring refrain, but useful in practice ; nor should we scorn the metre which comes (with a past) from the very front of the chorus.

These three muscles are moved at will with finger and thumb, not only across the radial shaft (clothed by supinator), but also *against* the neighbouring mass of common extensor that lies more firmly bound. Presently their mobility will help us to find and rip a seam in the cloak covering the neuromuscular sandwich of supinator and posterior interosseous nerve.

The rest of the muscles.—Excluding the mobile wad, the muscles on the back of forearm lie in two layers—superficial and deep. We can now proceed, as we did in front, to make a manual mnemonic for the *surface layer*. But this time we must carry the ball of the opposite thumb round *behind* the forearm and place it on the back of the lateral epicondyle (Fig. 74). The oblique thumb again (but rather awkwardly) marks an oblique muscle—the anconeus. The index will press the belly of extensor carpi ulnaris against the ulnar shaft ; the middle finger marks extensor digiti quinti, while the ring finger lies on the rather fixed mass of common extensor. (The little finger is not used at all.)

The deep layer.—There is good reason to remember the arrangement of this layer (Fig. 75). All its tendons (excepting sometimes that of proprius) can be seen in one's own hand ; all go to thumb or index. They are four in number : abductor pollicis longus, extensor pollicis brevis, extensor pollicis longus, extensor indicis proprius. Except for the first—the long abductor which springs from *both* bones—the tendons point towards their bone of origin.

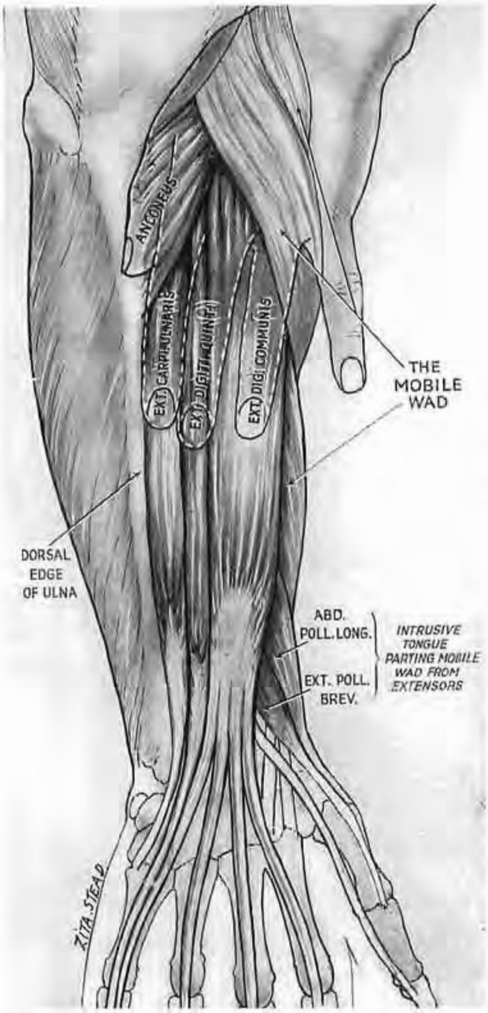


Fig. 74

Manual mnemonic for posterior superficial muscles of the forearm

The ball of the opposite thumb lies this time on the *back* of lateral epicondyle. The index finger feels the dorsal edge of ulnar shaft. (Again the little finger plays no part.)

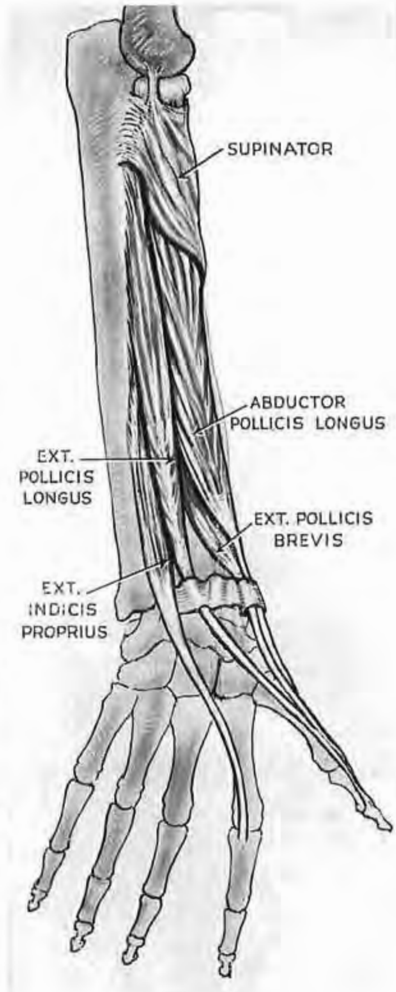


Fig. 75

The deep posterior muscles

These send their tendons to thumb or index. (Supinator also makes a wide posterior appearance. It has already been described and dealt with in the front of the limb.)

So the short thumb extensor comes from radius ; the long extensor and the proprius from ulna. (The bellies of two muscles of the thumb, the long abductor and short extensor, thrust out a common fleshy tongue between the mobile wad of three and the more fixed extensor of the fingers—a tongue which helps to emphasise the parting we shall presently exploit.)[1]

We have seen (p. 101) how the posterior interosseous nerve (the deep terminal branch of musculospiral) enters the anterolateral face of supinator and slopes obliquely down across the striped grain of that muscle. The nerve can be found on the *back* of radial shaft at a quite definite point—three fingerbreadths distal to the head of radius (Fig. 76). I would stress the fact that this measurement must be made neither on the outer side of the bone, nor on its posterolateral face, but on the back only.

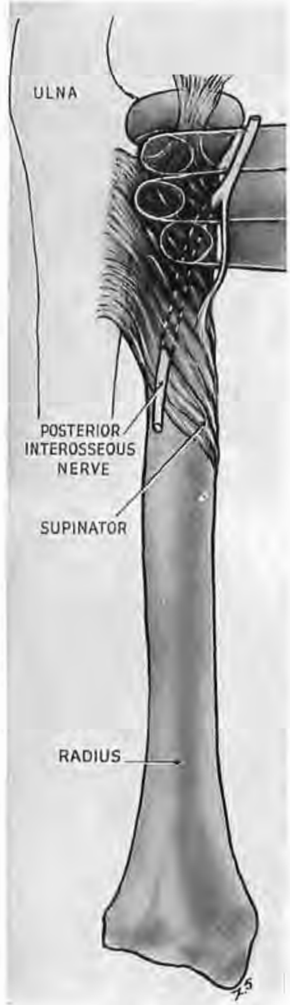


Fig. 76

The three-finger method of locating the posterior interosseous nerve (deep terminal branch of musculospiral)

The test must be applied at the *back* of radius. The edge of the proximal finger-tip fits the curve where head joins neck. Sandwiched in fibres of supinator, the nerve crosses the back of radius deep to the pulp of the distal finger-tip.

EXPOSURE OF THE POSTERIOR INTEROSSEOUS NERVE (THE DEEP TERMINAL BRANCH OF THE MUSCULOSPIRAL) FROM BEHIND

This nerve, they say, is difficult to find. The fault, however, is not in the *nerve*. Its faithful rendezvous upon the back of radius (like that kept by the parent trunk in skirting round the humerus) is just another of those ‘ certainties ’ on which it is unfair to bet.

THE OPERATION

Incision.—The knife should aim to go between extensor carpi radialis brevis and extensor digitorum communis (Stookey and

[1] The site of separation is further marked by a pit which can be felt in the *prone* forearm just proximal to the bulge of the intrusive ‘ tongue,’ a handbreadth above the wrist. The finger-tip receives a sharp impression of the shaft of radius, unpadded at the bottom of the pit by tendon or by belly.

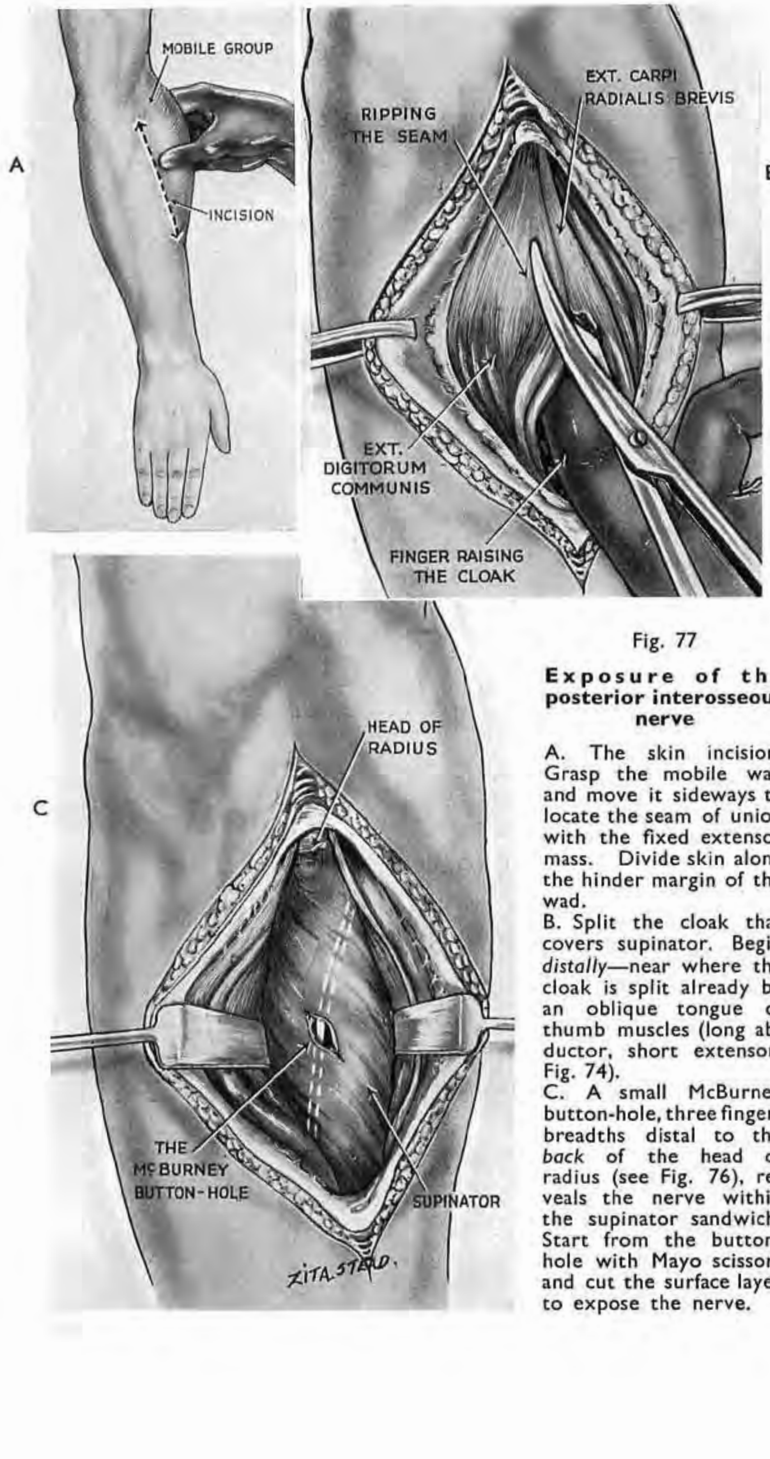


Fig. 77

Exposure of the posterior interosseous nerve

A. The skin incision. Grasp the mobile wad and move it sideways to locate the seam of union with the fixed extensor mass. Divide skin along the hinder margin of the wad.

B. Split the cloak that covers supinator. Begin *distally*—near where the cloak is split already by an oblique tongue of thumb muscles (long abductor, short extensor, Fig. 74).

C. A small McBurney button-hole, three finger-breadths distal to the *back* of the head of radius (see Fig. 76), reveals the nerve within the supinator sandwich. Start from the button-hole with Mayo scissors and cut the surface layer to expose the nerve.

Guild, 1919).[1] With the patient's forearm prone the line for separating these is found at once by grasping with a thumb and finger the wad that lies just distal to the outer epicondyle. This wad (whose hindmost belly *is* extensor carpi radialis brevis) moves readily against the much less mobile mass of the communis. We therefore easily locate the *hinder* margin of the wad and trace it with a knife (at first through skin) a generous handbreadth down the limb, from outer epicondyle (Fig. 77, A).

When we have opened deep fascia—beginning distally—we verify once more the plane between the zones of different mobility, and take advantage of their distal parting to separate them cleanly. This pair of bellies covers supinator with a loose cloak, ripped easily in two where it divides but toughly fused above within a fibrous hood. A finger, therefore, working from below, will help to raise the cloak for clean division (Fig. 77, B). Then we shall see the striped (and sometimes flashy) supinator belly. The nerve (sandwiched, remember, in the muscle) slopes *across* the stripe. Measure then with the tips of three fingers—side by side and touching—from the *back* of the neck of radius; the posterior interosseous nerve lies on the *back* of shaft deep to the distal finger (Figs. 76 and 77, C). And here a small McBurney cut, splitting the supinator grain, will let us glimpse the flat and whitish shape of our objective; and then, if we transect the grain, we shall expose the nerve. A word of caution: the sandwich is *thin*, so do not nick the nerve with your McBurney (Fig. 77, C).

EXPOSURE OF THE HEAD AND NECK OF RADIUS FROM BEHIND

It has been said that any cut made behind the proximal end of radius will expose the head and neck of the bone safely, provided that it stops before we wound the posterior interosseous nerve. This statement is soundly based: extensor digitorum communis takes origin within a hood of tough fibrous tissue that lies behind the radial head and yields no plane of cleavage. We shall accordingly divide the skin and then cut down on bone, using three fingers to locate the nerve (Fig. 76), and cutting only to the second nail. (The cut should also reach two fingerbreadths *above* the epicondyle to leave room for resection.)

[1] S. Guild and B. Stookey, *Surgery, Gynecology and Obstetrics*, 1919, **28**, 612.

TWO EXPOSURES IN THE HAND

A MEDIAL APPROACH TO MID-PALMAR SPACE AND ULNAR BURSA [1]

Adams McConnell—the first by many years, this side of the Atlantic, to give Kanavel's work a practical appreciation—described in 1913 a method of draining the mid-palmar space (*Medical Press and Circular*, 1913, **95**, 328). His dorsal incision of the web between the fingers, remote alike from vessels, nerves and palmar skin, has not been bettered.[2] It is a part, however, of its charm that surgery leaves room for new alternatives. The one I shall describe gives access to the space and ulnar bursa. Advantage will be taken of a loop-hole in the *edge* of the hand to gain entry to the palm. The skin incision, like McConnell's, leaves no palmar scar, and gives dependent drainage both of space and bursa when the hand lies semi-prone, in its most comfortable attitude.

ANATOMY

The floor of the palm is formed by alternate bones and interosseous muscles covered with a loose carpet of fascia—a carpet separated from the ulnar bursa by mid-palmar space. The bursa wraps the superficial and deep flexor tendons of middle, ring, and little fingers and almost fills the space.[3]

The way in.—Opponens of the little finger, the deepest hypothenar muscle, lies on the ulnar side of palmar floor concealed by the short flexor and the large bulge of abductor. It is fastened proximally to the hook of unciform and to the transverse carpal ligament; distally, to the distal three-quarters of the fifth

[1] *The Lancet*, 1939, **1**, 16.

[2] There is, I know, a prejudice abroad which holds that specialists, like cobblers, should stick to their last. And so, in case it were believed by any that the hand of *one* employment "hath the daintier touch," the fact is worth attention that this neurosurgeon was amongst the first (if not the first) to integrate Cushing's technique outside America; certainly first (as Dandy notes) to use ventriculography in Europe. But never any man's disciple—a grade most fit to rank beside the legendary *second* class of the nipponic Order of Chastity.

[3] *Mid-palmar space.*—A healthy, undissected man has no mid-palmar space—if "space" means "interval"; nor has he any popliteal space: *both* are convenient myths (though most anatomists long looked coldly at Kanavel's). There is, however, in the hand between the palmar floor and ulnar bursa a fissile plane—an '*espace décollable*' that easily distends and shows a special shape when it becomes unstuck by pus or by injection.

metacarpal shaft, on the ulnar side of the volar face (Fig. 78). Between these terminal attachments there is a small 'free' portion of opponens belly, and this when isolated by a touch becomes the palmar boundary of a loop-hole that is framed behind by fifth metacarpal base and the joint it makes with unciform—the hamate of B.N.A. (Fig. 78). An instrument thrust through this loop-hole

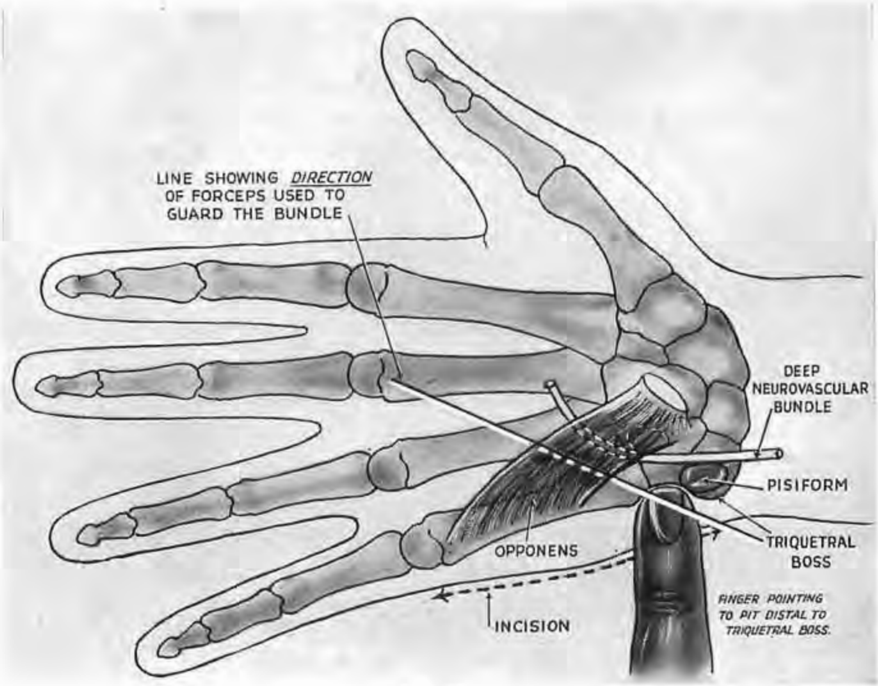


Fig. 78

The landmarks

1. The triquetral boss from which the knife will cut along the edge of the fifth metacarpal.
2. The pit marked by the finger distal to the boss. Opposite the pit we find the loop-hole to mid-palmar space. A forceps *aimed* along the sloping line goes through the loop-hole *for a fingerbreadth* to form a tangent that will guard the curving ulnar bundle.

meets and overcomes a check; then it goes on and either penetrates mid-palmar space, or is a menace to the deep branch of the ulnar nerve or to the ulnar bursa.

The hypothenar fascia.—The check is caused by the most radial portion of a fascia that sheathes the hypothenar muscles and loops them loosely, like a sling, to the shaft of fifth metacarpal. The toughness of the membrane and its erratic spread to neighbouring interosseous bellies vary in different persons.

The *deep branch of ulnar nerve* with its satellite artery and veins must be carefully avoided. The branch leaves the main trunk opposite the pisiform and sinks gradually into the palm between the two superficial muscles of the hypothenar group—abductor and short flexor of the little finger. It enters the field of operation as it grazes the ulnar side of the hamate (or unciform) hook and is there bridged or embraced by opponens fibres. Just distal to the hook the nerve and vessels fortunately bend thumbwards, almost at right angles, and, fortunately again, the bend lies a good fingerbreadth radial to the loop-hole's mouth. Whatever instruments we turn toward the space will thus avoid the nerve if pointed distally—for choice, towards the *head* of third metacarpal (Fig. 78).

THE OPERATION

The site allows a long, benignly placed, incision, and this will give advantage for inspection combined with thorough drainage of a part where pus is liable to pocket. Blind use therefore of the loop-hole as a means of access should be condemned ; it is a mere lucky breach that must be *widened* for surgical attack.

Position.—With the patient recumbent under general anæsthesia, either pronate and turn his upper limb till the *back* of the thumb rests on the table, or bring the half-pronated forearm into contact with the biceps. The first position has the merit of ulnar-flexing the hand and thus relaxing skin and muscle so that bony landmarks are easy to feel. At the moment, however, of making the incision the wrist should be propped straight to unwrinkle the skin.

TWO WAYS OF FINDING THE PIT WHICH IS THE SURFACE GUIDE.—(1) Run a thumbnail down the ulnar border of the patient's *wrist* ; a thumb's breadth dorsal to the pisiform the nail will override a boss—the cuneiform or os triquetrum—and sink at once into a pit just distal to the boss. In this depression (which dips towards the loop-hole) the nail will touch the hard base of the fifth metacarpal immediately behind the hypothenar mass. (2) The thumb, slid proximally *up* the subcutaneous edge of fifth metacarpal, is checked by the triquetral boss exactly opposite the pit (Fig. 78).

The incision.—This begins on the triquetral boss and goes—through skin only—down the whole length of metacarpal edge ; skin and fat are reflected just sufficiently to show the bone and let us see the fascia that ensheathes the bulging belly of abductor—

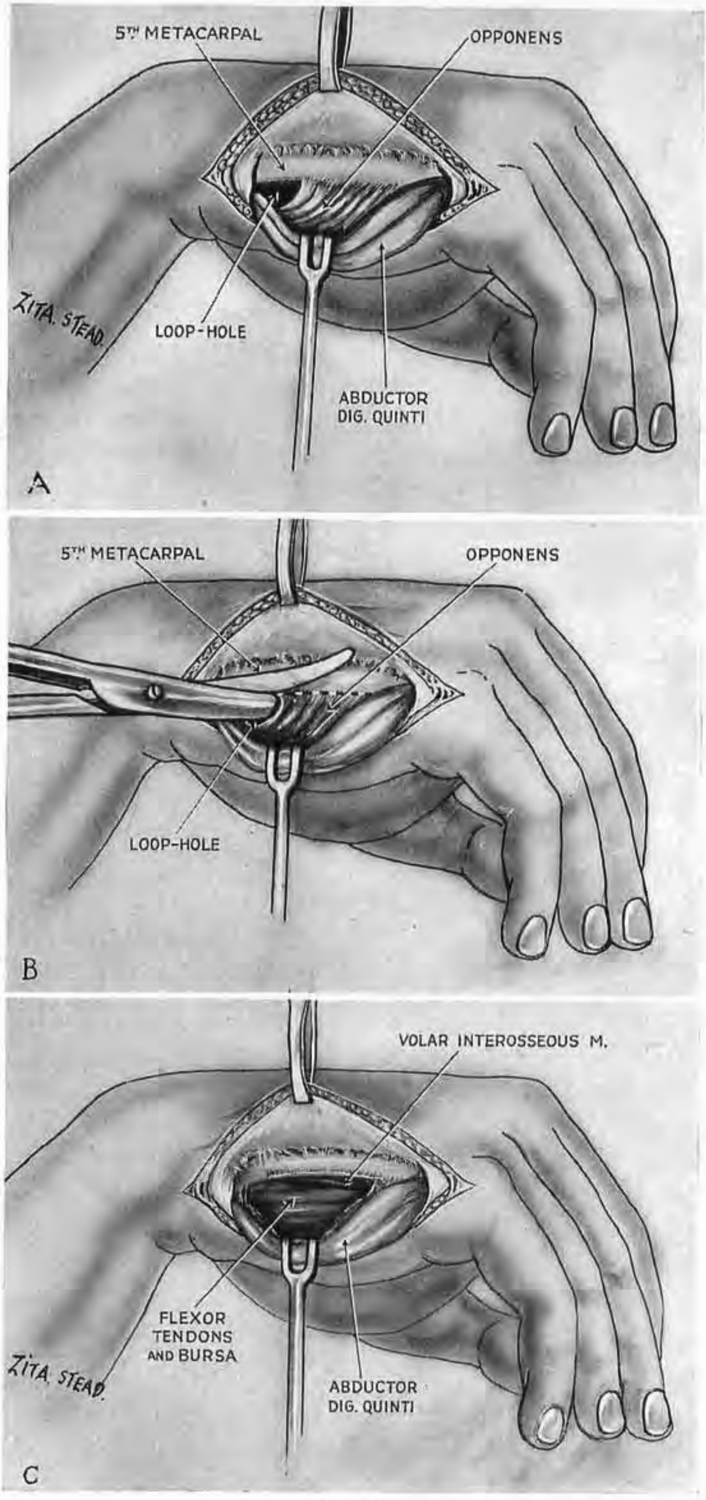


Fig. 79

The loop-hole and the exposure.—To find the loop-hole, A, slit the fascia binding abductor belly to the ulnar edge of fifth metacarpal. Retract the belly palmwards. Open a deeper fascia that lies just palmar to the metacarpal base. Deep to the fascia a touch of blunt dissection will dislodge the short 'free' portion of opponens towards the palm and so define the loop-hole. B. Widen the loop-hole by severing opponens. Open the fascia deep to the muscle. C. Retraction draws the severed opponens palmwards, with the abductor. The ulnar bursa lies with its back to mid-palmar space.

a muscle recognised by its mobility before and during operation. Pick up this fascia close to the ulnar edge of metacarpal; open it lengthwise without injuring abductor or the *dorsal* branch of ulnar nerve, which runs along the sheath; liberate and retract the muscle palmwards. Then pick up and divide a thin fascia just in front of the metacarpal base.

It is now easy to define the loop-hole (Fig. 79, A) by raising the free portion of opponens from bone with the blunt nose of Mayo scissors; withdraw and open the scissors; pass one blade through the loop-hole and cut opponens close to metacarpal shaft, dividing all but distal fibres (Fig. 79, B); open the screen of fascia beyond. The ulnar bursa then appears—through the wide gap between hypothenar mass and palmar floor—bulging into the mid-palmar space (Fig. 79, C). Widen the gap still further by flexing the hand, especially its little finger. The deep neurovascular bundle can be protected during this operation with a closed forceps introduced along the palmar floor in the direction shown in Fig. 78—a safeguard which I owe to Wing-Commander R. Shackman, my former colleague.

The final scar escapes the rubs of ordinary use.

MEDIAL APPROACH TO THE DEEP TERMINAL BRANCH OF THE ULNAR NERVE

Exposures made through palmar skin can sometimes be exceedingly refractory; and, if we use that route to deal with the deep ulnar branch, we split the palm from wrist to finger leaving the scar ill-placed.[1]

Instead we can adapt for this exposure the medial approach to the mid-palmar region (p. 116), prolonging the incision four fingerbreadths into the forearm (Fig. 81, A), disarticulating the pisiform, and—for the widest view—dividing the opponens.

THE OPERATION

After incising skin and fascia look for the ulnar trunk beside and radial to the tendon of flexor carpi ulnaris; then trace it down to where it ends—just radial to pisiform—in deep and superficial branches. The *deep* branch lies next pisiform, and after trivial contact with its fellow nerve dips through the hypothenar mass.

[1] See Fig. 10 in a paper by C. A. Elsberg and A. H. Woods: *Archives of Neurology and Psychiatry*, 1919, 2, 658.

We know already how to find the distal part of the deep branch in the palm, opposite opponens loop-hole (p. 117) ; in order, therefore, to expose the nerve in continuity from the medial side we must displace the interrupting block of pisiform.

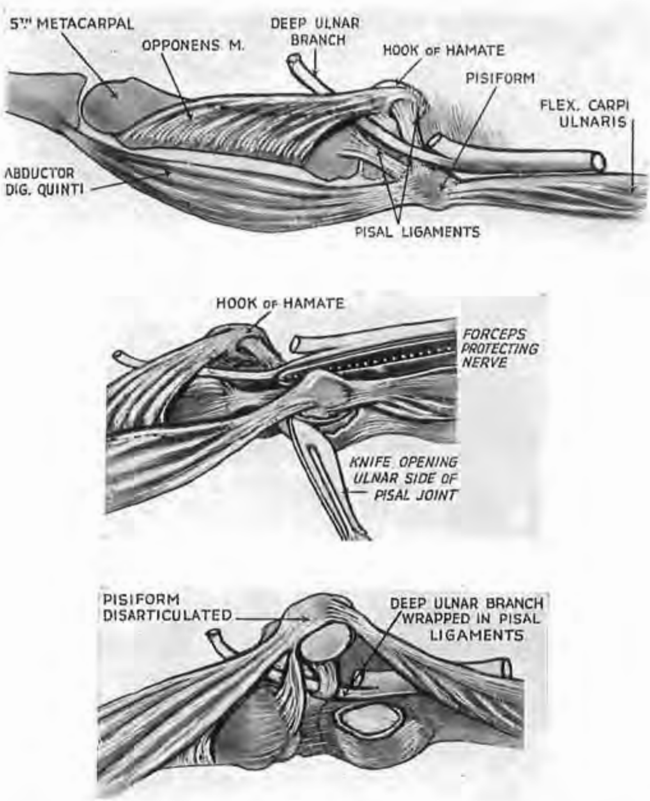


Fig. 80

Exposure of the deep terminal branch of ulnar nerve (anatomy)

Diagrams which show that when the pisiform is raised within its band (like a patella), and turned in such a way that the articular facet looks to the ulnar side, the pisal ligaments wrap round the nerve. A. The undisturbed lay-out seen from its ulnar aspect. B and C are ulnar views : B. The pisal joint is opened while we guard the nerve with intervening forceps ; C. The pisiform is raised and turned to let the ligaments be cut in safety close to the facet.

Mobilising the pisiform.—The tendon of flexor carpi ulnaris inserts on this bone, and abductor digiti quinti springs from it ; the pisiform, therefore, detached from the wrist, remains (like a patella) in the band formed by these muscles. The bone is also moored by two ligaments which pass distally, and they are reinforced with fibres from the tendon of flexor carpi ulnaris (Fig. 80); the weaker goes to the base of fifth metacarpal; the other—a stout cord (crossed by the deep ulnar branch) goes to the hook of hamate. When therefore we lift the pisiform from its articulation (guarding the nerve with a metal tool while we divide the capsule of the joint) we see only the *start* of the deep branch; the rest of its proximal portion is wrapped in ligaments (Fig. 80). These can be safely cut if the mobile bone (still in its band of muscle) is turned through a right angle so that the oval articular facet looks to the ulnar side; then we divide the ligaments against the pisiform.

The deep branch may now be traced through fibres of abductor and opponens digiti quinti, and seen to great advantage (Fig. 81, B). But, if we need a wider access, dividing the opponens near the edge of metacarpal will let us reach two extra fingerbreadths of this short nerve (Figs. 79, B and 81, C).[1]

THE INNOCENT EFFECT OF PISAL DISARTICULATION

My readers should be warned. A piece of pure anatomy—most properly consigned in other pages of the book to footnotes—lies right ahead, and those who steadily pursue the by-pass of the text must now skip over an intrusion. But some that disarticulate the pisiform may wonder why they have not spoilt the 'flexor retinaculum' (a recent alias of transverse carpal ligament). For in the current text-books which favour that nomenclature the proximal and ulnar corner of the retinaculum is fixed (they say) to pisiform. Detachment therefore of the pisiform should free the corner and impair restraint. It, happily, does nothing of the kind.

To think it might is to suppose that an important piece of band

[1] I have recently seen a lad whose superficial and deep branches of a left ulnar nerve had been completely divided at the wrist. Six months after the accident he was operated on by Mr J. C. Sugars, using the method here described. After continuing a forearm incision into the hand by making it curve closely round the heel of the hypothenar eminence, detachment of the pisiform gave clear access for suture and was followed by no bowstringing of flexor tendons. Recovery of function has so far been remarkable.

Fig. 81

Exposure of the deep ulnar branch (the operation)

A. Mobility test to find abductor digiti quinti; incisions for the skin and fascia follow its dorsal edge and then go up the forearm—ulnar to flexor carpi tendon.
B. The disarticulated pisiform, detached from pisal ligaments, stays in its compound band. Obscuring fibres of opponens are cleared away to bare the nerve. For wider access mobilise opponens with Mayo scissors; cut through the muscle close beside the edge of fifth metacarpal (B and C).

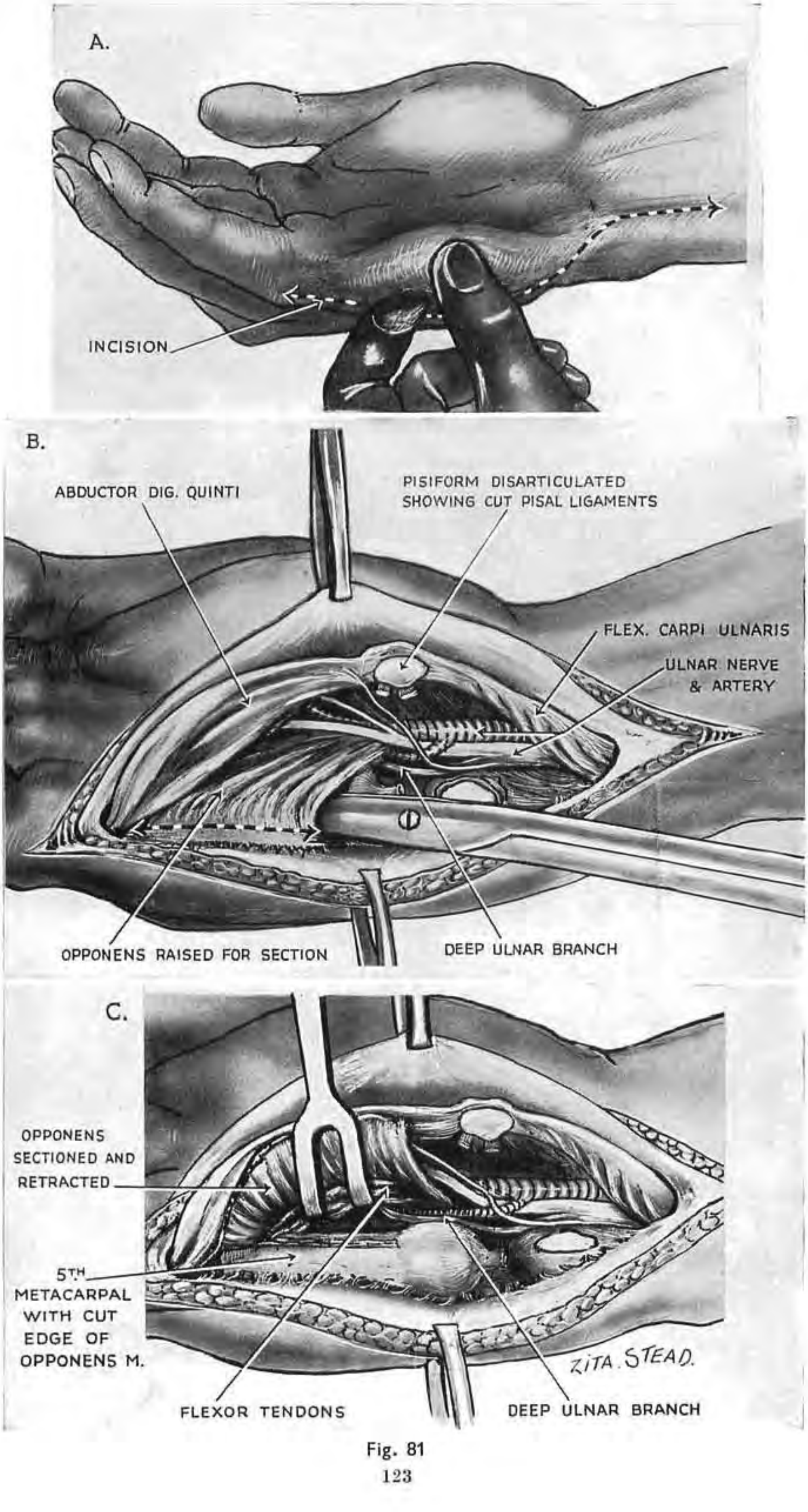

A.
INCISION
B.
ABDUCTOR DIG. QUINTI
PISIFORM DISARTICULATED
SHOWING CUT PISAL LIGAMENTS
FLEX. CARPI ULNARIS
ULNAR NERVE
& ARTERY
OPPONENS RAISED FOR SECTION
DEEP ULNAR BRANCH
C.
OPPONENS
SECTIONED AND
RETRACTED
5TH
METACARPAL
WITH CUT
EDGE OF
OPPONENS M.
FLEXOR TENDONS
DEEP ULNAR BRANCH
ZITA. STEAD.

Fig. 81

concerned in curbing tendons would be attached for *that* upon a mobile and unstable bone—an almost blasphemous conception.

Like every legend, this account of pisiform attachment is the distortion of a fact. There *is* a retinaculum whose proximal and ulnar corner is firmly fixed—not in a futile way to pisiform, but to the stable cuneiform (the os triquetrum of the Basle nomenclature). Then comes that old appurtenance of fairy-tale, the cloak of darkness: the cardinal attachment to the cuneiform is hidden underneath extrinsic fibres from the pisal coat. These fibres spread in part from the insertion of flexor carpi ulnaris, and partly (on a deeper plane) from an oblique band that also coats the pisiform—a portion of the so-called *radio*carpal ligament. But far from working as a retinaculum this band (which springs, despite its name, from ulnar styloid) *relaxes* when the wrist is palmar flexed. The retinaculum of course does not; and it is just in virtue of its ulnar corner, fixed as it is to cuneiform, that flexor tendons are restrained from tearing pisiform away from carpus.

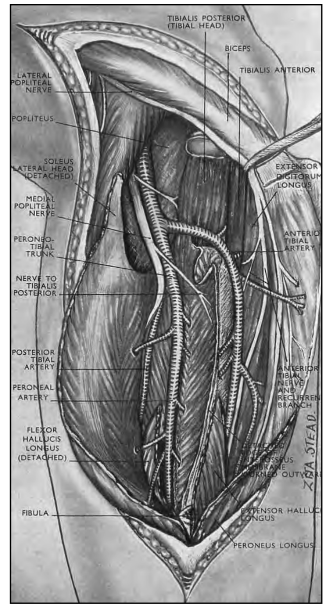
Current descriptions of this quondam transverse carpal ligament (once the anterior annular) call for revision. First, it is wrong, I think, to give the structure *as a whole* the name of flexor retinaculum; it does not all by any means deserve it. Something also might be done to better the nomenclature which lumps as "radiocarpal" a ligamentous band whose proximal extremity springs only from the *ulna*—a band that may be found to play a part in wrenching off the styloid process in a Colles fracture.

The golden age of ligaments is gone. So has the silver age (with John Bland-Sutton); and rust begins to gather.

This book is a surgical classic -- it is famous for what a reviewer described as its “use of the English language and its literature to present cold fact with such warmth and life”. It has been unavailable for some time, but is now available as a facsimile of the second edition with the addition of a short bibliographical note by Arnold K. Henry himself.

An exposure is the route by which the surgeon gains access to the structures on which he or she wishes to operate, and the exposures can be extended if necessary (hence the term “extensile exposures”). Many of the exposures described in this book are still in use, but it will mainly be obtained for the literary pleasure of reading.

As it has been out of print for some time, many surgeons will be pleased to have the opportunity of adding this famous work to their libraries. The Lancet: “There is no pleasanter way of revising anatomy”. British Medical Journal: “The distinguished author is to be congratulated on this further development of a masterpiece”.



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