FASCIOCUTANEOUS FLAPS

FASCIOCUTANE LAPPEN

Proefschrift

Ter verkrijging van de graad van Doctor
aan de Erasmus Universiteit Rotterdam
op gezag van de Rector Magnificus
Prof. Dr. A.H.G. Rinnooy Kan
en volgens besluit van het college van dekanen.
De openbare verdediging zal plaatsvinden op
22 april 1988 te klokke 16.00 uur

Door

DAVID ERSKINE TOLHURST

geboren te Wellington, Nieuw Zeeland.

1988

DRUKKERIJ PASMANS B.V., 's-GRAVENHAGE

Promotie Commissie:

Promotoren	: Prof. Dr. J.C.H. van der Meulen Prof. Dr. J. Voogd
Overige Leden	: Prof. Dr. B. van Linge Prof. Dr. H.A. Bruining

For Sonia, Camilla and Charlotte

CONTENTS

Chapter 1

INTRODUCTION

My own awareness of the surgical significance of the deep fascia can be traced back to an essay written in 1978 which was published two years later (Tolhurst 1980) and which concerned the subject of restoring durable skin cover for exposed bone. In a section on "the extended application of muscle flaps" I drew attention to an observation made principally in the operating room, that blood vessels which perforate the superficial surface of muscles on their way to supplying the overlying skin, ramify on both sides of the deep fascia. Shortly thereafter the probable significance and value of these vessels was proposed by Pontèn (1981).

About that time the concept of independent myocutaneous vascular territories (Mc Craw and Dibbell, 1977) was beginning to take hold but the deep fascia, sandwiched between muscles and the skin, was largely regarded as an isolating layer of dense, avascular fibrous tissue from which flaps comprising skin and subcutaneous tissue could be rapidly stripped by blunt dissection with minimal bleeding. Indeed authorities on anatomy invariabley make no mention of the blood supply of the deep fascia nor of any vessels related to it (Last 1963).

There is thus little wonder that generations of students and surgeons manifested no interest in the vascular characteristics of the deep fascia. Instead it was hailed as a relatively avascular staging-post by general surgeons on the way into the abdomen or by orthopaedic surgeons preparing to assault bones situated beneath muscles.

Plastic surgeons engaged in reconstructive surgery have from the inception of their specialty realised the importance of designing skin flaps endowed with a reliable blood supply. It was thought and taught that in general the length of any flap should not exceed the width (the so-called one to one rule) although in certain situations such as the face, the length could be judiciously extended because of the richer blood supply in the area. Many flaps were modified by trial and error and those that proved reliable gained not only a place in the textbooks but were also frequently dignified by the name of a surgeon.

This empirical approach gave way by degrees to a series of somewhat laborious experiments and tests on patients which were designed to clarify the blood supply in flaps and also the length, width rule or rather to remove the latter from the list of non-scientific findings.

The first of these investigations to be but on a scientific footing and which was of practical value was that of Hynes (1948) who used atropine injections in flaps and tube pedicles to estimate their vascularity. If the blood flow through the tissue was good, absorbtion and distribution of atropine in the general

circulation produced changes in pulse rate, pupil dilatation and mouth dryness that could be measured in terms of rapidity of onset. In general the results of this technique were very reliable and allowed early and safe division of cross leg flaps and tube pedicles. This test had advantages over the injection of fluorescein in tube pedicles as quantification was possible.

In the heyday of the tube pedicle these and other tests such as photoelectric plethysmography brought more credence to the reliability of tube pedicle transfer but the surgical technique itself was cumbersome and time-consuming. Although it would not give up the struggle easily, its days were numbered.

It was Milton (1969) who began to steer thinking along the right lines by showing that the length of flaps raised on the belly of pigs immediately superficial to the deep fascia did not survive proportionately to their width. There seemed to be a limit in his experiments to surviving length and it became clear to him that the inclusion of a large vessel in the pedicle was the deciding factor. Thus narrow flaps appeared only to become more necrotic because of the absence of a good vessel in the pedicle.

Looking further, he soon realised that flap survival is not proportional to width, since the oxygen consumption is proportional to area not length. Putting it another way, when length is doubled as well as width, four times as much tissue is asked to survive on only twice as much blood.

Esser (1917) had shown that the skin and subcutaneous pedicle of flaps could be totally dispensed with as long as the feeding and draining vessels were preserved and Milton's experiments confirmed this and actually demonstrated a 10% increase in average expected survival length in such flaps.

All of Milton's conclusions, it is important to remember, were based on flaps raised immediately superficial to the deep fascia. His support of Esser's clinical findings were further elaborated upon in his views on the necessity of transfering flaps on vascularised pedicles if progress were to be made. What he did overlook was the possibility that the essential vessels may be lying deeper than the boundary between the fat and deep fascia!

As late as 1971 considerable energy was still being expended on devices to calibrate the blood flow through tubed pedicles (Stranc et al.) but in the article that followed Stranc's, Antia and Buch (1971) reported on a successful revascularised free dermofat graft, which although not performed with the help of the microscope, was the forerunner of the free flap vogue. Earlier Ger (1966) had started down the right and shorter path by using muscle flaps, covered with skin grafts to close recalcitrant skin defects. Unfortunately his work at first went largely unnoticed by plastic surgeons but by dint of repeated publications in general surgical journals the potential of muscle flaps began to be appreciated.

Pers et al. (1973) were amongst the first to employ muscle flaps outside the leg for repair of wounds, correction of contour defects, cover of exposed vessels and closure of fistulae. Their article also stressed the value of muscle flaps in the leg and included a classical photo of a prepared leg dissection showing areas which could be covered by transposed muscle flaps.

It is my belief that this work was not accorded the acclaim it deserved, probably due to the fact that the musculo-cutaneous flap stole the limelight from the middle 1970's onwards. The idea of transfering muscle and skin together as a flap was documented by Owens (1955) but lay dormant until Hueston et al. (1968) again demonstrated the value of a "compound pectoral flap". Orticochea (1972) realised that there were vessels "crossing the barrier" between muscle and skin but it was unquestionabley Mc Craw and his various co-workers who clarified this and applied their understanding of the vascular connection between muscle and skin to a whole series of musculo-cutaneous areas from 1976 onwards.

Whilst the new currents of muscle and free flap transfer began to flow into the literature those of the tube pedicle had dwindled to a trickle. Stell's reappraisal of his studies on random skin flaps raised superficial to the panniculus carnosus (1977) attracted little interest for the search was now well under way for axial flaps and other reliable flaps with a predictable blood supply.

It is not the object of this work to single out one technique and acclaim it as superior. As plastic surgery evolves it becomes apparent that like tools in a workshop, some methods of repair remain in very common use. Just as the hammer and screw driver are constantly put to work, so too are skin grafts and flaps. Muscle flaps, though less frequently employed, are indispensable and were the most valuable "flap find" of the sixties. During that decade the delto-pectoral flap emerged and Mc Gregor's (1973) investigation of its blood supply prompted him to coin the new classification of random and axial flaps. Random skin flaps are flaps which derive their blood supply from small, variable vessels whilst axial flaps contain a dominant, constant and substantial vessel which is readily identifiable. Such flaps are designed to include the feeding vessel in their base so that the vessel tends to run in the long axis of the flap. The deltopectoral flap itself must be attributed to Bakamjian (1965) and he clearly mentions the advisability of including the deep fascia in the flap. As early as 1946, Shaw et al had described an axial flap based on the superficial epigastric vessels and its use in 31 cases without complication proved its value and reliability. The flap was raised at the level of Scarpa's fascia but the importance of including the vessels was stressed.

Flap classification, as will be explained in the chapter 3, has proved difficult and until now no satisfactory system has been devised. Mc Gregor's idea of classifying flaps according to their blood supply was a step forward but when applied to the deltopectoral flap it did not tell the whole story. This flap was primarily a fasciocutaneous flap, a term not yet in use in the sixties and early seventies, principally nourished by a series of axial vessels which were protected if the plane of dissection was kept beneath the deep fascia. Since the inclusion of the deep fascia was not sufficiently stressed in descriptions of the use of this flap, I believe that in some cases failure of this usually reliable flap was due to faulty dissection in too superficial a plane, resulting in damage to important blood vessels.

It is strange that although several surgeons advocated inclusion of the deep

fascia in some leg flaps, sporadically over the years, it was not until the 1980's that this remarkabley simple concept began to receive the attention it deserved.

It may be considered inappropriate to end this section by returning to the past, but perhaps it is in the future that long forgotten work will be rediscovered, to shed more light on the blood supply of cutaneous territories. After all it took nearly the entire lifetime of modern plastic surgery before the work of Manchot (1889) began to attract attention. Milton manifested some interest in this work but it was only in 1983 that an English translation was published.

Manchot's description of "hautarterien" has thus quite recently become well known and although the skin territories he described are related to somewhat larger arteries than those with which we are now concerned, his dissections and skin maps are in many respects quite accurate. The same too, can be said of Salmon's more sophisticated investigations (1936) but to make matters worse for the English speaking surgeon, both authors had locked their secrets away in a "foreign" language. If these 2 books had been translated 40 years ago, it is conceivable that they would have provided the stimulus or short cut to what we have so very recently discovered.

Object of the study.

Despite the important advances in wound repair up to the beginning of the 1980's, there were still groups of patients with chronic ulcerating skin lesions of the leg, osteomyelitis of the tibia, compound fractures of the leg and skin loss exposing bone, joints or tendons, whose morbidity was severe. Long periods of hospitalisation still frequently occurred whilst conservative measures or repeated debridement and skin grafting were tried. This was both costly and depressing.

Muscle and musculo-cutaneous flaps were not always suitable for these patients, nor were all surgeons equipped to perform these procedures. The laborious cross-leg flap was thus often chosen as a definitive attempt to close these wounds but it too necessitated 2 operations and a long period of hospitalisation. In one series of 165 cases (Morris et al 1978) the average time in the cross-leg position was 26 days and the time to healing 64 days in the recipient area and 43 days in the donor area. In this series 94% of the 165 flaps were successful.

The authors summarised the other potential dangers and disadvantages of this technique: there was concern about necrosis, venous thrombosis, later breakdown from trauma to an insensitive flap and the cosmetic deformity.

I was very much interested in the repair of lower leg defects since I was not infrequently confronted with these unfortunate patients. Despite my enthusiasmm for muscle and musculo-cutaneous flaps and the rising star of micro-surgery, it still seemed that a simpler solution was not only needed but must be available.

It was my singular good fortune to be both in the audience and awake during the winter meeting of the British Association of Plastic Surgeons just before

luncheon in December 1979, when Pontén delivered his paper entitled "The super flap or the extended use of local flaps on the lower leg".

The superflap was anatomically nothing more than a fasciocutaneous flap and this appeared to be the answer to the riddle which had perplexed me and others for so long. I accordingly proceded to verify Pontén's claims for myself and along with others such as Barclay (1983) and Casey (1984) to confirm its value as a reconstructive aid in lower leg skin defects.

It was not long before I conceived the idea of applying the principle in other areas of the body where skin grafts and various flaps had proved unsatisfactory. First it was necessary to carry out anatomical dissections to demonstrate the existence of the deep fascia in these regions and to identify the fascial plexus which at first was thought to be largely responsible for distributing perforating branches to the skin. In the fresh cadaver leg the plexuses and perforators were not difficult to demonstrate but on the back they were not so readily visible even after dye injection.

At first the fasciocutaneous flap was used exclusively in the lower leg but just as musculocutaneous flaps had slowly been used on the trunk, so too were fasciocutaneous flaps. Our first posterior thoracic flaps for the correction of axillary contractures were by present standards very modest. They were undertaken in the place of criticism that the "deep fascia did not exist outside the leg". But cadaver dissections had proved this to be nonsense and our tentative exploration of the technique in the trunk was soon rewarded and strengthened by the readily visible vascular plexuses on both sides of the deep fascia.

In most cases the axillary contractures were caused by burn scars or contracted skin grafts and previous experience had taught us that split skin graft corrections of the axilla had frequently to be repeated once or twice before full abduction was restored. Incomplete take of the skin graft was particularly problematical and usually ended in a very poor result. Furthermore immobilisation of the arm with an "aeroplane" splint was extremely awkward for the patient and in theory should be maintained for 3 months or until the contractile phase of the wound healing had passed.

As our experience with fasciocutaneous flaps in the axilla increased we realised that not only were more "daring" flaps possible, but also that immobilisation for more than 4 or 5 days was unnecessary.

Thus a one stage, simple and reliable flap correction replaced the split skin graft. An added benefit stemmed from the logical realisation that if these survived due to the blood supply from the fascia, then old skin grafts in the area should also survive as part of fasciocutaneous flaps and this they did. Previous teaching had condemned the use of skin flaps in grafted areas.

Smaller scarred or grafted areas in the lower leg were also incorporated in fasciocutaneous flaps with success, although in general if alternative tissue is available it is preferable.

Elsewhere a variety of flaps using the fasciocutaneous principle have subsequently been used but my initial observations and clinical experience were based on the series of flaps used in the lower leg and posterior trunk for the

correction of axillary contractures (Tolhurst et al 1983). The injection studies and dissections of Cormack and Lamberty during the last 5 years have done much to clarify the anatomy of the vessels related to the deep fascia. Not only have they proposed a number of fasciocutaneous flaps suitable for local use, but they have also described several flaps suitable for use as free flaps.

The advent of the fasciocutaneous flap has not by any means supplanted muscle and musculocutaneous flaps but rather it has given us a useful alternative with specific characteristics which make these flaps suitable for many different problems throughout the body.

In short this work is not only an account of how I and my colleagues strove to benefit from the advantages of the fasciocutaneous flap but it traces the development and the establishment of this flap as a versatile and widely available means of reconstructing a variety of defects.

Conclusions

There is no denying that the introduction of the fasciocutaneous flap in the lower leg has been the springboard for the investigation of the deep fascia and its related blood vessels throughout the body. This in turn had resulted in the dissemination of the fasciocutaneous flap throughout the body, such that it has become a valuable part of our reconstructive armoury.

The fasciocutaneous flap was first used in the lower leg and it continues to be a useful technique where there is a good surgical indication. The indications in the leg and the use of the fasciocutaneous principle elsewhere, will be elaborated upon in the remainder of this thesis.

References Chapter 1

1. Antia, N.H. and Buch, V.I. (1971) Transfer of an abdominal dermo-fat graft by direct anastomosis of blood vessels. Brit. J. Plast. Surg. 24, 15.
2. Bakamjian, V.Y. (1965) A two-stage method for pharyngoesophogeal reconstruction with a primary pectoral skin flap. Plast. Reconstr. Surg. 36, 173.
3. Barclay T.L., Cardoso E., Sharpe D.T. and Crockett D.J. (1982) Repair of lower leg injuries with fasciocutaneous flaps. Brit. J. Plast. Surg. 35: 127.
4. Casey R.P. (1984) Le lambeau cutaneo-aponevrotique aux membres inferieurs: sa cartographie. Techniques et indications. Thèse pour le doctorat en médicine.
5. Cormack, G.C. and Lamberty, B.G.H. (1986) The arterial anatomy of skin flaps. Churchill Livingstone, Edinburgh.
6. Esser, J.F.S. (1917) General rules used in simple plastic work on Austrian war-wounded soldiers. Surg. Gynec. Obstet. 34, 737.
7. Ger, R. (1966) The operative treatment of the advanced statis ulcer: A preliminary communication. Am. J. Surg. III. 659.
8. Hueston, J.T. and Mc Conchie, I.H. (1968) A compound pectoral flap. Australian and New Zealand J. Surg. 38, 61.
9. Hynes, W. (1948) A simple method of estimating blood flow with special reference to the circulation in pedicled skin flaps and tubes. Brit. J. Plast. Surg. 1, 159.

10. Last, R.J. (1963) Anatomy. Regional and applied. Deep fascia. J. and A. Churchill Ltd. London. 4.
11. Mc Craw, J.B., Massey, F.M., Shanklin, K.D. and Horton, C.E. (1976) Vaginal reconstruction with gracilis myocutaneous flaps. Plast. Reconstr. Surg. 58, 176.
12. Mc Craw, J.B. and Dibbell, D.G. (1977) Experimental definition of independent myocutaneous vascular territories. Plast. Reconstr. Surg. 60, 212.
13. Mc Gregor, I.A. and Morgan, G. (1973) Axial and random pattern flaps. Brit. J. Plast. Surg. 26, 202.
14. Manchot, C. (1889) Die Hautarterien des Menschlichen Korpers. F.C.W. Vogel, Leipzig.
15. Milton, S.H. (1969) The tubed pedicle flap. Brit. J. Plast. Surg. 22, 53.
16. Orticochea, M. (1972) The musculo-cutaneous flap method: an immediate and heroic substitute for the method of delay. Brit. J. Plast. Surg. 25, 106.
17. Owens, N. (1955) Compound neck pedicle designed for the repair of massive facial defects: Formation, development and application. Plast. Reconstr. Surg. 15, 369.
18. Pers, M. and Medgyesi, S. (1973) Pedicle muscle flaps and their applications in the surgery of repair. Brit. J. Plast. Surg. 26, 313.
19. Pontén, B. (1981) The fasciocutaneous flap: its use in soft tissue defects of the lower leg. Brit. J. Plast. Surg. 34, 215.
20. Salmon M. (1936) Arteres de la peau. Masson, Paris.
21. Shaw D.T. and Payne R.L. (1946) One stage tubed abdominal flaps; single pedicle tubes. Surg. Gynecol. and Obstet. 83: 205-209.
22. Stranc, W.E., Fox, R.H. and Muir, I.F.K. (1971) The blood flow in tubed skin pedicles; calibration for the photoelectric plethysmograph. Brit. J. Plast. Surg. 24, 10.
23. Tolhurst, D.E. (1980) Skin and Bone. Brit. J. Plast. Surg. 33, 99.
24. Tolhurst, D.E., Haeseker, B. and Zeeman, R.J. (1983) The development of the fasciocutaneous flap and its clinical applications. Plast. Reconstr. Surg. 71, 5, 597.

Chapter 2

THE DEEP FASCIA AND ITS ASSOCIATED BLOOD VESSELS

Brief mention has already been made of the fact that standard textbooks on anatomy devote no space to the blood supply of the deep fascia or its relation to neighbouring blood vessels. This is understandable since at first sight there appear to be only a very few insignificant looking vessels in the areolar tissue immediately superficial to the deep fascia. Furthermore when deliberately exposing the superficial surface of muscles, any perforating vessels running towards the skin from the muscle layer will be divided. Unless one specifically looks for such vessels they will go largely unnoticed.

In order to answer for once and for all, the question whether or not the deep fascia is itself in any way responsible for the increased reliability and viability of flaps it would really be necessary to raise flaps of the same size in the same areas with and without the fascia. This simple experiment is at present being undertaken in pigs but in a way it has already been done, albeit in a non-scientific manner, for over the years skin flaps in the lower leg gained an evil reputation and on the whole were abandoned in favour of muscle, or musculo-cutaneous flaps. But when Pontén included the deep fascia in a series of flaps in the lower leg a dramatic improvement in the reliability of the flaps was observed, so much so that flaps were raised which once would have been deemed unthinkable.

There is absolutely no doubt that in some situations the deep fascia is able to conduct enough blood for survival to a skin flap, isolated as an island flap on a "random" fascial pedicle (Moscona et al., 1985). This is a safe technique if the fascia contains an axial vessel or the flap is of the ladder type. Initially, before the 3 main vascular systems responsible for the blood supply of the skin were more fully understood, it was thought that inclusion of the deep fascia in skin flaps would tip the scales in favour of survival but it is now apparent that this is not always likely to be true.

Historical development

Although Pontén (1981) must be given the credit for drawing attention to the value of the deep fascia in flap surgery, he did not investigate the anatomical vascular system related to the fascia in any detail. As has so often been the case in the past, a publication by Schäfer (1975) in the German literature was overlooked by Pontén and others. Schäfer's description of the 3 main vascular systems supplying the skin was not too far from what we now understand to

be the case and in particular his observations on the fascial plexuses and their link with the intermuscular septal vessels, really formed the basis of our current concept of the fasciocutaneous vascular system.

Soon after Pontén's publication of his clinical results of flaps in the lower leg, Haertsch (1981) defined what he called "the surgical plane in the lower leg" as lying deep to the deep fascia but Tolhurst et al. (1982) were the first to reiterate the relevant anatomical vascular details as originally described by Schäfer (1975). Our work was again principally devoted to the clinical extensions of the fasciocutaneous flap but at about this time, Cormack and Lamberty began to direct their energies to more detailed anatomical investigations which were first published in 1983. I believe they independantly came upon what were, somewhat confusingly called perforators, which passed from main arteries in the depths of the lower limb via the intermuscular septa to the deep fascial plexuses. In fact these vessels would be better called "conducting" arteries as they do not perforate the septa or fascia in the same way as do the musculocutaneous vessels described by McCraw and Dibbell (1977).

In any case, Lamberty and Cormack continued to systematically describe a whole series of perforators in the limbs and upon this basis, to propose a variety of different fasciocutaneous flaps.

In the lower limb they quite rightly drew further attention to the concept of axiality in the fascial plexuses and this underlined the advice of Pontén (1981) and Barclay (1982) that fasciocutaneous flaps should be designed so that their long axis parallels that of the fascial plexus.

Cormack and Lamberty were primarily involved with cadaver studies but they used low pressure injections of micropaque which in large measure is probably the reason why their anatomical work has been accepted in clinical situations.

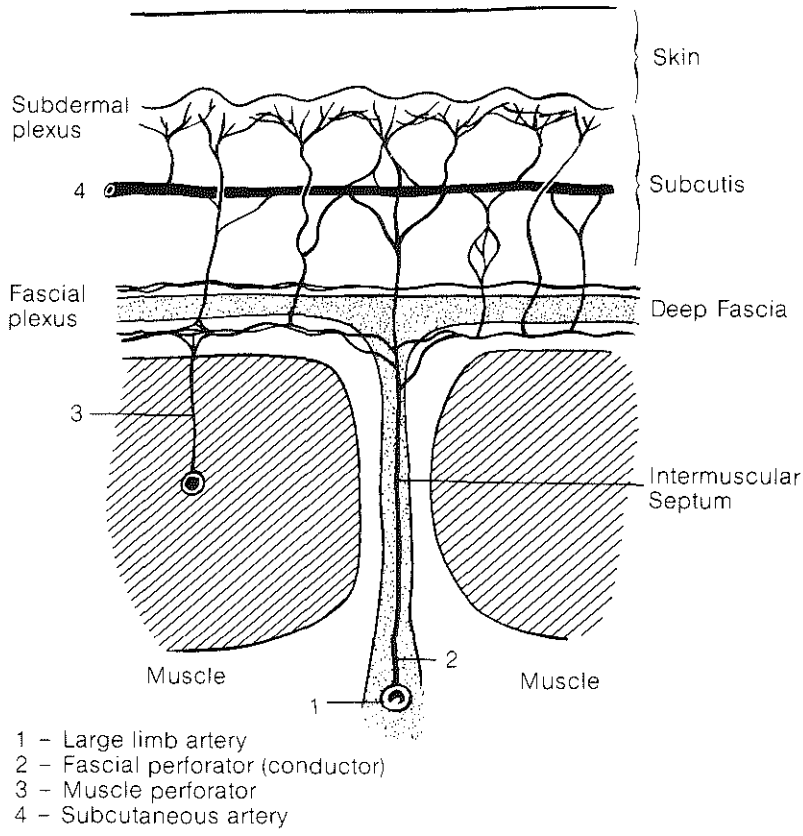
The Tripartite blood supply to the skin (Fig. 2.1)

At this stage it is appropriate to outline the 3 vascular systems which play a part in supplying the skin with blood. This concept was described by Tolhurst et al in 1982 and was based on the work of Schäfer (1975).

(1) *The direct subcutaneous system*

Here arteries, usually accompanied by veins, run in the subcutaneous fat, parallel with the skin surface. They appear to be confined to certain areas of the body, at least if they are 1 mm. ID. or larger in size. These larger vessels are familiar to surgeons who have raised axial pattern flaps in which they form the anatomical vascular basis. A well known example is the superficial circumflex iliac artery found in the groin flap.

It is not possible to state how these vessels reach the level of the subcutaneous fat in all situations, due to the great variations encountered throughout the body. Since the vessels tend to run in one axis for a considerable distance and are



2.1 Schematic representation of the tripartite blood supply to the skin.
Subcutaneous vessels, muscle perforating vessels and fascial conducting vessels clearly shown.
Note deep and superficial plexus related to deep fascia.

responsible for a certain "angiotome" or cutaneous vascular territory, it seems justifiable to lump them into one system.

Marty et al. (1984) described a subcutaneous system of vessels in the forearm and hand which they used as the basis for subcutaneous flaps. They implied that the fascia and the associated fasciocutaneous vascular system could be disregarded and perhaps have not been alerted to the tripartite vascular supply described here. In fact one cannot overlook their work since it reinforces one part of the tripartite concept, being an example of the direct cutaneous system of vessels. But it is wrong to condemn the deep fascia and its vascular system and to say that there are no indications for their inclusion in skin flaps. It may be of little use in some areas but it clearly is advantageous in others.

(2) *The musculocutaneous system*

This system is the basis of the musculocutaneous flap which enjoyed a great vogue in the late 1970's and early 1980's. It is principally to McCraw that we are indebted for the discovery of this system which has been one of the great milestones in plastic surgery, unlike the tube pedicle which perhaps could be better termed a millstone.

In general muscle perforators run superficially from the vascular pedicle of broad flat muscles to perforate the muscle and the deep fascia and eventually anastomose with branches of the other 2 systems. However these perforators appear to have a dominant role in supplying the area of skin overlying the muscle.

A full account of this system can be found in the textbooks of Mathes and Nahai (1979, 1982) and Cormack and Lamberty (1986).

(3) *The fasciocutaneous system*

This system will subsequently be described in greater detail but for the sake of completeness is summarised here. A brief outline of its anatomy in the lower leg follows as this affords the simplest, representative description.

The main arteries in the limb send branches or "conducting vessels" via intermuscular septa to the deep fascia. At this level plexuses of small vessels are formed on both sides of the fascia with fascial perforators linking the two. From the superficial plexus, vessels continue towards the surface, eventually supplying the subdermal plexus and the skin. There is a tendancy for the vessels of the plexuses to run predominantly in the long axis of the limb but there are many transverse and oblique anastomoses. Furthermore the larger septal vessels may continue superficially to form the basis of an axial or ladder fasciocutaneous flap.

The interrelationship of the systems

There are unquestionabley anastomoses between the three systems, although in various areas each system may be responsible for the dominant supply of a vascular cutaneous territory. As our knowledge of these unfolds, largely through the painstaking work of anatomical studies, a whole series of skin flaps, each appropiate for a specific area of the body is being documented. In each area there may be an overlap or even an alternative choice of basic flap design possible depending on the vascular anatomy. Thus musculocutaneous or fasciocutaneous flaps can be used with equal safety in the calf region and with some restrictions in length to breadth ratio, a skin flap based on the direct cutaneous vascular system may even be employed in the same area.

McCraw et al. (1978) were aware of the possibility of combining a fasciocutanious element with a musculocutaneous flap when they extended the gastrocnemius musculocutaneous flap towards the malleolus.

It should be stressed that some flaps which were originally thought to be axial cutaneous flaps are in fact axial fasciocutaneous flaps. An example of such a flap is that supplied by the saphenous artery and this conforms to the type B fasciocutaneous flap described in Chapter 3. This in itself may be difficult for some to understand but the nomenclature confuses the issue even further when one is confronted by the atomic system of flap classification which I have proposed.

In this system a flap raised to include the deep fascia has been listed as a fasciocutaneous flap, irregardless of its vascular supply. Lamberty prefers to classify a flap as fasciocutaneous only if its blood supply is predominantly from the fasciocutaneous system of vessels. But what are we to call a deltopectoral flap which includes the deep fascia but relies for its blood supply on the cutaneous arteries ? Anatomically it is a fasciocutaneous flap and so it should be called. The purists should be satisfied if in addition one specifies the type of blood supply and the " atomic system" makes allowance for just such a possibility. This is not purely an academic matter as the speed and safety of the operation is increased if one raises a deltopectoral flap for example, as a fasciocutaneous flap. Thus the acceptance of the classification has practical as well as logical implications.

Finally, it is not at the moment possible to fully explain the interrelationship of the vessels of the "tripartite cutaneous vascular system". Clearly the anatomical need or development of each system in certain areas can be explained by the underlying muscles, fascial septal and main arteries. The perfusion, as opposed to the vascular anatomy is a much more complicated matter. Elucidation of the skin perfusion seems to rest on animal experiments but these may not always be applicable to the human.

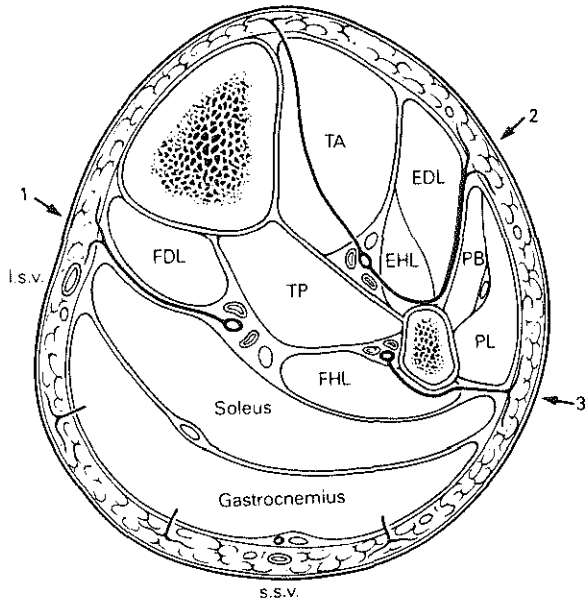
Since there is clearly an overlap of the 3 cutaneous systems in many areas one system may have a regulatory role, whilst the others maintain a basic perfusion. It is not inconceivable that musculocutaneous perforators may be able to shunt significant volumes of blood between the skin and underlying muscles as conditions of body temperature and muscle activity dictate.

Observation of the skin overlying areas of intense muscle activity has lead me to believe that this is quite feasible. One has only to compare the palm of the left hand, which is kept immobile, with the right, whilst the fingers on the right are rapidly flexed and extended, to see a clear skin colour difference between the two sides. In this area there are however few or insignificant muscle perforators but in the legs under similar conditions, such a skin colour difference would not be surprising.

The fasciocutaneous vascular system

As a rule it is over broad, flat muscles that the skin is largely supplied by muscle perforators, whilst the fascial perforators (or conductors) tend to reach

the deep fascia and then the skin via septa between long, thin muscles (Fig. 2.2).



TA —tibialis anterior
EDL —extensor digitorum longus
EHL —extensor hallucis longus
PB —peroneus brevis
PL —peroneus longus
TP —tibialis posterior
FHL —flexor hallucis longus
FDL —flexor digitorum longus
s.s.v. —short saphenous vein
l.s.v. —long saphenous vein
perforators from:
1. posterior tibial artery
2. anterior tibial artery
3. peroneal artery

Schematic transverse section through the mid-calf showing locations of fasciocutaneous perforators (or conducting vessels 1, 2, 3) in the intermuscular septa.

(With the kind permission of Cormack and Lamberty).

2.2 Conducting vessels running in intermuscular septa to deep fascial level.

In the lower limb once the "conducting" vessels have reached the level of the deep fascia they branch to form plexuses. Haertsch (1981) described a plexus superficial to the fascia but Tolhurst et al. (1982) had observed a plexus, albeit less striking, deep to the deep fascia. Lang (1962) and as mentioned earlier, Schäfer (1975) had also seen two plexuses and there is now agreement that in the lower leg widespread vessels perforate the deep fascia and link the 2 systems. Elsewhere it is usually the superficial plexus which is dominant. Arterioles and capillaries less than 0.1 mm ID run on and through the deep fascia. We have always contended that the plexuses are best seen in the living tissue, where no tourniquet is used.

From the deep fascia's superficial surface small vessels proceed superficially towards the skin until they reach the level of the subdermal plexus. There are anastomoses between these vessels and also between them and small vessels of the other 2 vascular systems supplying the skin.

In Chapter 3 variations in the "conducting" vessels and their ramifications are seen to be responsible for a number of different types of fasciocutaneous flaps which form the basis of Cormack and Lamberty's classification. These variations slightly complicate what is otherwise a simple and readily understood system. Differing factors play a part in the characteristics of each type of flap. For example in the type A flap which one can raise on the medial side of the leg, there are undoubtedly useful vascular contributions directly or indirectly via the base of the flap from the continuation of the saphenous artery below the knee and the musculocutaneous perforators over the gastrocnemius.

The type B flap depends largely for its blood supply on a single vessel of moderate size which emerges from the depths of the limb in an intermuscular septum and which continues to run for some distance at the level of the deep fascia so that it can be truly said to provide a dominant axial blood supply to the flap. Clearly in such a flap, an island of skin should be able to survive on the fascial pedicle. In addition it may be wiser to include subcutaneous tissue in the flap in the hope that small direct cutaneous vessels will contribute to the safety of the flap.

The third type of flap, type C is exemplified by the radial forearm flap. This has been called a ladder flap because the flap is supported by a series of "conducting" vessels which pass along a fascial septum from the radial artery to the deep fascia. These "conducting" vessels can be likened to the rungs of a ladder.

Venous drainage from fasciocutaneous flaps is both through venae comitantes where large vessels are present or through the normal subcutaneous system of veins.

Various theories have been proposed to account for the axiality of vessels related to the deep fascia and it is not too difficult to accept that growth and development in the limbs is responsible for the longitudinal orientation. Elsewhere the arrangement of collagen fibres may be responsible for the vessel axiality. In the lower part of the forearm however, the fascial fibres tend to run more horizontally in contradistinction to the proximal fascial fibres. In both areas the fascial plexus is principally oriented in the same direction as the fascial fibres.

The regional orientation of fasciocutaneous vessels

The following account is based on the anatomical investigations of Cormack and Lamberty which have been summarised in their book (1986). It is more of an outline of the fasciocutaneous "conductors" and plexuses throughout the body and has been included here because of the importance of obviating errors in design of fasciocutaneous flaps.

Foremost in the surgeon's mind when it is contemplated to raise a fasciocutaneous flap, should be these questions:

1. Is there a layer of deep fascia with significant vessels at the site?
2. What is the axial arrangement of the vessels?
3. Are there "conducting" vessels in the vicinity and from which main vessels do they arise?

The upper arm

The skin overlying the deltoid is supplied by musculocutaneous perforators but elsewhere "conductors" arise from the brachial, superior ulnar collateral, radial collateral and middle collateral arteries and pass superficially via the medial and lateral intermuscular septa.

Medially there are 5 or 6 conducting vessels, the cutaneous branch of the largest being the basis of the medial upper arm flap. Laterally vessels reach the deep fascia via septa on both sides of the brachioradialis. The middle collateral artery is larger and has a more important role in supplying the skin.

The fascial plexus is orientated more obliquely than horizontally.

The lower arm

There are strong similarities in the fascial vascular layout between the lower leg and forearm. Most of the blood supply to the skin is from fasciocutaneous conductors arising from the radial, ulnar, anterior and posterior interosseus arteries.

The fascial plexus is longitudinally orientated in the proximal part of the forearm but more transversely in the distal third. On the dorsal aspect the conducting vessels from the posterior interosseus artery are mainly transversely or obliquely orientated.

The thigh

The musculocutaneous perforators forming the basis of various musculocutaneous flaps such as the gracilis and tensor fasciae latae flaps are well known. The less well known fasciocutaneous conductors arise from the femoral and profunda femoris arteries as might be expected. They reach the deep fascia along the edges of sartorius anteromedially, between the hamstrings posteriorly and via the lateral intermuscular septum laterally. There is one exception laterally where the ramifications of the conducting vessels are to be found in the subcutaneous fat, somewhat superficial to the iliotibial tract and fascia lata which here correspond to the deep fascia.

The fascial plexus in the thigh is variable, being more prominent anteromedially, scanty anterolaterally and moderate posteriorly. The plexus where well developed, is parallel with the sartorius and posterior cutaneous nerve of the thigh but elsewhere mostly oblique or horizontal. Due to the great muscle bulk in the thigh there is no significant demand for fasciocutaneous flaps.

The lower leg

Here the conducting vessels arise from the anterior tibial, posterior tibial and peroneal arteries and reach the deep fascia mainly via the septa on both sides of the peroneal muscles and the septum between soleus and flexor digitorum longus. Conducting vessels are also present elsewhere, for example between the two heads of gastrocnemius.

The fascial plexuses are predominantly longitudinal in orientation and this is the reason why long flaps in the lower leg are possible and indeed preferable in that no delay is needed and manipulation plus fixation in cross-leg flaps is greatly fascilitated.

The trunk

The deep fascia is less well developed on the trunk and in keeping with the preponderance of broad, flat muscles one would expect the musculocutaneous perforators to play a dominant role in supplying the skin.

The well known conducting vessels which do supply a fascial plexus, useful in the design of flaps to correct axillary contractures are the scapular and parascapular branches of the circumflex scapular artery. In addition branches of the thoraco- acromial axis below and lateral to the pectoralis major are claimed by Reid and Taylor (1984) to play a significant part in supplying the fascia and skin in this region.

On the lateral side of the trunk, Fisher (1985) has described conducting vessels from the intercostal arteries which support transversely orientated fasciocutaneous flaps.

References Chapter 2

1. Barclay, T.L., Cardoso, E., Sharpe, D.T. and Crockett D.J. (1982) Repair of lower leg injuries with fasciocutaneous flaps. Brit. J. Plast. Surg. 35, 127-132.
2. Cormack, G.C. and Lamberty, B.G.H. (1986) The arterial anatomy of skin flaps. Churchill Livingstone, Edinburgh.
3. Cormack, G.C. and Lamberty, B.G.H. (1982) The forearm angiotomes. Brit. J. Plast. Surg. 35, 4.
4. Fisher, J. (1985) External oblique fasciocutaneous flap for elbow coverage. Plast. Reconstr. Surg. 75, 51.
5. Haertsch, P.A. (1981) The surgical plane in the leg. Brit. J. Plast. Surg. 34, 464-469.
6. Haertsch, P.A. (1981) The blood supply to the skin of the leg: a postmortem investigation. Brit. J. Plast. Surg. 34, 470-477.
7. Lang, J. (1962) Über die Textur und die Vascularisation der Fascien. Acta Anatomia 48, 61-94.
8. McCraw, J.B. and Dibbell, D.G. (1977) Experimental definition of independent myocutaneous vascular territories. Plast. Reconstr. Surg. 60, 341-352.

9. McCraw, J.B., Fishman, J.H. and Sharzer, L.A. (1978) The versatile gastrocnemius myocutaneous flap. Plast. Reconstr. Surg. 62, 15.
10. Marty, F.M., Montandon, D., Gumener, R. and Zbrodowski, A. (1984) The use of subcutaneous tissue flaps in the repair of soft tissue defects of the forearm and hand. Brit. J. Plast. Surg. 37, 95.
11. Mathes, S.J. and Nahai, F. (1979) Clinical atlas of muscle and musculocutaneous flaps. C V Mosby, St Louis.
12. Mathes, S.J. and Nahai, F. (1981) Classification of the vascular anatomy of muscles: Experimental and clinical correlation. Plast. Reconstr. Surg. 67, 177-187.
13. Mathes, S.J. and Nahai, F. (1982) Clinical applications for muscle and musculocutaneous flaps. C V Mosby, St Louis.
14. Moscona, A.R., Govrin-Yehudain, J. and Hirshowitz, B. (1985) The island fasciocutaneous flap: a new type of flap for defects of the knee. Brit. J. Plast. Surg. 38, 512.
15. Pontén, B. (1981) The fasciocutaneous flap; its use in soft tissue defects of the lower leg. Brit. J. Plast. Surg. 34, 215.
16. Reid, C.D. and Taylor, G.I. (1984) The vascular territory of the acromiothoracic axis. Brit. J. Plast. Surg. 37, 194-212.
17. Schäfer, K. (1975) Das subcutane Gefäss-System (untere Extremität): Micropräparatorische Untersuchungen. Gegenbaurs Morphologisches Jahrbuch, Leipzig. 121, 492-514.
18. Tolhurst, D.E. and Haeseker, B. (1982) Fasciocutaneous flaps in the axillary region. Brit. J. Plast. Surg. 35, 430.

Chapter 3

FLAP CLASSIFICATION

This chapter has been included in order to put the fasciocutaneous flap in proper perspective. It is not a special flap, endowed with magic properties. Like the muscle and musculocutaneous flaps, it is a soft tissue flap with characteristics which make it suitable for use in specific situations. Chief amongst these is the need for a thin, supple flap with a reliable blood supply.

A comprehensive classification of flaps. The atomic system

Before the reader turns the page, I can assure him or her that there is no need to be alarmed by the mention of the atomic system, as the two main parts of this classification are merely compared to the nucleus and electron shells of an atom. Beyond this no further demands are made on a knowledge of physics.

Systems of classification have always been of value, not only in the teaching but also in the practice of medicine where they provide an orderly method of approaching and solving clinical problems. In no branch of plastic surgery is this more true than in flap surgery, in which a wide variety of tissues as well as secondary characteristics of flaps are available for consideration.

A comprehensive and logical system for classifying all the diverse characteristics of flaps appears so far to have eluded the minds of those concerned with this subject. This is probably in part due to the large number of new flaps which have been introduced over the last 10 years. The other main difficulty is in designing a simple classification which can embrace all the variations in tissue content, flap form and blood supply to mention but a few variables.

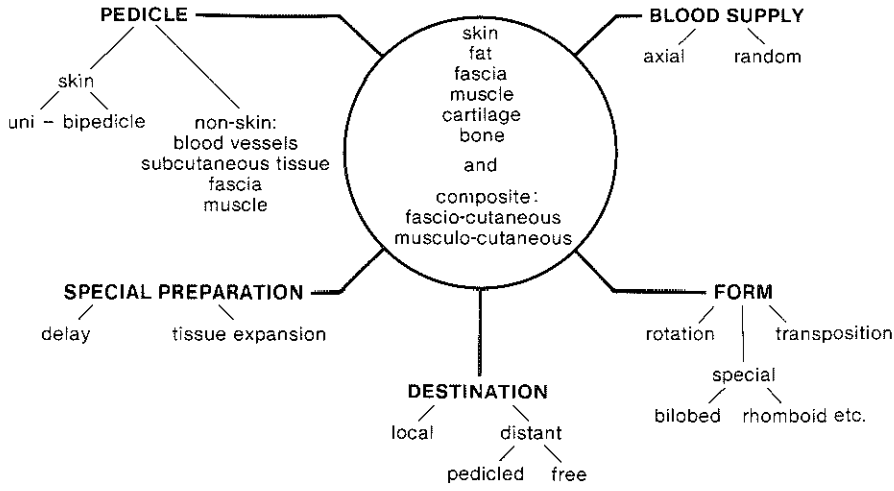
The atomic system.

The classification proposed resembles a simple atom in that it comprises a nucleus into which the tissue components of flaps can be placed and an outer shell system into which the secondary but nonetheless important characteristics of flaps can be fitted (fig. 3,1).

In reducing the basic structure of the system to 2 main components, the classification remains simple which is a great advantage, especially in the teaching of plastic surgery to those with a limited interest and knowledge of the specialty.

The atomic system allows additions in both compartments as new techniques develop.

The scheme depicted in figure 3.1 is, in the interests of clarity, not intended to be exhaustive. For example many different shaped flaps of minor importance could be included under the "form" heading. Likewise in the "nucleus" various combinations of tissues not found here are conceivable and I have only listed the commonly used types of composite flaps.



3.1 The atomic system of general flap classification.

The reason that rotation and transposition flaps are to be found under the "form" heading is that the techniques themselves virtually dictate the shape of these flaps.

Island flaps have not been separately listed but fall under the category of non-skin pedicle flaps. Up until quite recently most surgeons understood an island flap to be an area of skin nourished by a vascular pedicle but now that muscle and fascia are frequently found as flap components, they too can act as pedicles to support skin islands.

Other simple systems, such as those based on the blood supply of flaps, were obviously only dealing with strictly limited aspects of flap surgery. Attempts to include all the other flap variables have resulted in separate, unsystematic lists. These are usually incomplete, which is understandable, considering the recent proliferation of new flaps. In one book on flaps, the subject was dealt with according to areas of the body but this resulted in a cumbersome and repetitive system.

Finally I should like to touch on a few questions of nomenclature. One still encounters the tautological term "pedicle flaps", a term to be condemned since a flap by definition must remain attached to the body by some sort of tissue or pedicle.

In the index of some journals, grafts and flaps have for some years been

lumped together under one heading "grafts and flaps" which suggests that there may still be some widespread uncertainty over nomenclature.

The advent of microsurgery has confused this issue very definitely as we are now confronted with two names for the same thing. An example is the so called "revascularised muscle graft", also endowed with the epithet of "free muscle flap". This is a matter which can occupy many hours of fascinating but fruitless discussion.

Classification of fasciocutaneous flaps.

In a letter to Plastic and Reconstructive Surgery in 1984 Cormack and Lamberty wrote that skin flaps raised to include the deep fascia should not automatically be classified as fasciocutaneous flaps since the fascia may have little or nothing to do with the blood supply of some flaps.

This is a totally untenable suggestion! The tissue content of fasciocutaneous flaps is inescapabley such that there is no other logical name available than a fasciocutaneous flap. The sun which is round and usually emits bright light and warmth cannot be called something else just because when it is partially obscured by a cloud or eclipsed by the moon, its shape and qualities are altered.

Certainly in the lower leg the inclusion of fascia appears to confer circulatory advantages and elsewhere it can hardly be deemed dangerous. By raising skin flaps with fascia, amongst other advantages, the dissection is fascilitated and subcutaneous vessels are protected. Thus skin flaps which are designed to include a layer of deep fascia over their whole area should be classified as fasciocutaneous flaps.

Subclassification of fasciocutaneous flaps.

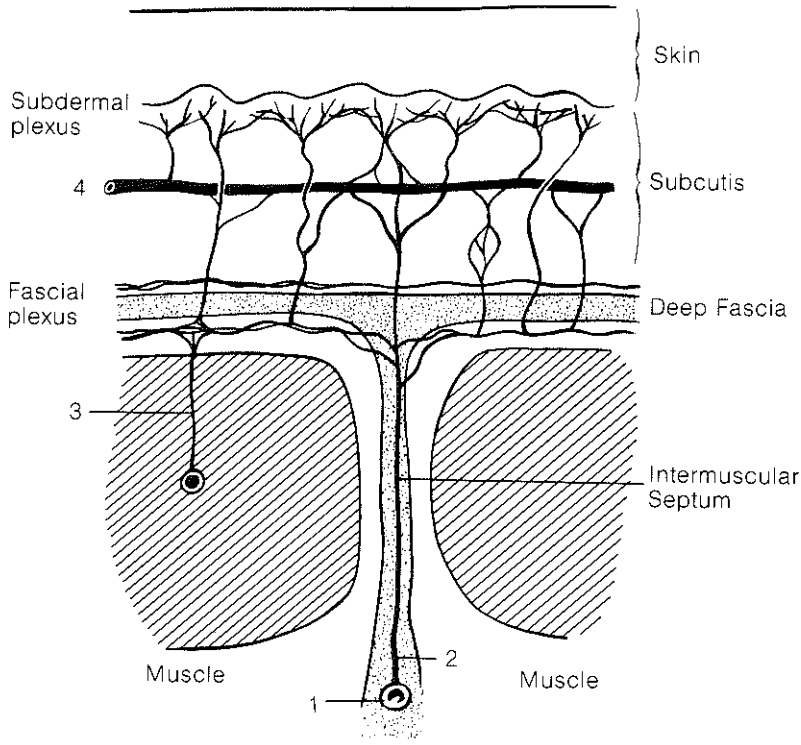
Cormack and Lamberty (1984) later went on to classify fasciocutaneous flaps according to their patterns of vascularisation. In the light of recent developments, especially in the field of free flaps, their classification is a welcome addition to their extensive work on the blood supply of fasciocutaneous flaps.

The background to the present concept of the vascular anatomy of the skin and subcutaneous tissue is fully discussed in Chapter 2, as are also specific details of flap blood supply. Nevertheless it is worthwhile mentioning the basic vascular relationship that certain blood vessels have to the deep fascia and fascial septa again at this stage.

Lamberty and Cormack (1984) have summarised the three ways in which blood reaches the skin, as the direct cutaneous vascular system, the musculocutaneous perforating system and the fasciocutaneous system. This last is the one on which the classification of various fasciocutaneous flaps is based.

The major arteries of the body and in particular the limbs, tend to run in

the core or centre of each part and are often surrounded by muscles. Via the well known intermuscular septa, branches of the large arteries pass between muscles towards the surface until they reach the deep fascia. The deep fascia is in continuity with the intermuscular septa and at the level of the former, the vessels fan out to form a plexus on both sides of the fascia. From the superficial plexus branches then run superficially through the subcutaneous tissue to reach the subdermal plexus, which itself supplies the skin. (Fig. 3,2).

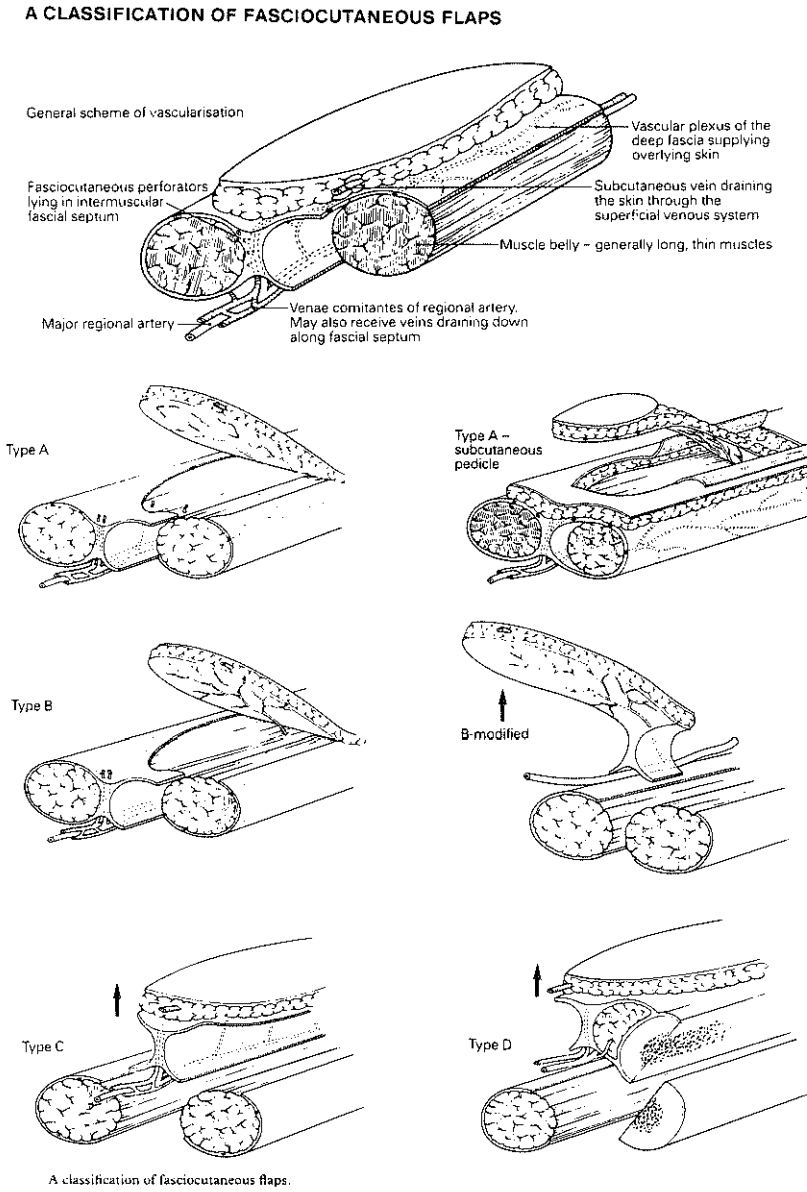


1 – Large limb artery
2 – Fascial perforator (conductor)
3 – Muscle perforator
4 – Subcutaneous artery

3.2 The blood supply to the skin. Note the deep and superficial plexus in relation to the deep fascia.

The classification.

Four types of fasciocutaneous flaps have been described by Cormack and Lamberty (1984) and in this work the first two types have also been given names (Fig. 3,3).



3.3 Schematic representation of the 4 types of fasciocutaneous flaps.

Type A. (Random fasciocutaneous flaps)

Here the blood supply of the flap is largely dependant on multiple perforators arising from the deep fascial plexus. Vessels from the intermuscular septa reach the deep fascia at different levels and contribute to the plexus on both surfaces of the fascia. These plexuses are predominantly oriented in the long axis of the limb and flaps should be raised in the same axis. Pontén's super flap is an example of this type.

Type B. (Axial fasciocutaneous flaps)

In these types, one encounters a single sizeable perforating vessel which is responsible for the flow through the plexus at the deep fascial level. The supraclavicular flap (Lamberty 1979) is an example and is described in Chapter 2. Other examples of flaps which fall into this group are the saphenous artery flap (Ackland et al. 1981) and the medial arm flap (Daniel et al. 1975).

Type C. (Ladder fasciocutaneous flaps)

Ladder flaps are supplied by multiple perforating vessels which run from a deep sizeable artery along an intermuscular septum to the deep fascia. At this level they form and support the fascial plexus. Such flaps must contain not only the skin and deep fascia but also the intermuscular septum and the main supplying vessel must be in continuity with the deep fascia. Examples of this type include the radial and ulnar forearm flaps and the distally based lower leg flap (Donski et al. 1983).

Type D

This is an extension of type C but the fascial septum is taken in continuity with adjacent muscle and bone. Such a flap can be raised as an extended radial or ulnar forearm flap (Biemer et al. 1983, Soutar et al. 1983).

References Chapter 3

1. Ackland, R.D., Schusterman, M., Godina, M., Eder, E., Taylor, G.I., Carlisle, I. (1981) The saphenous neurovascular free flap. Plast. Reconstr. Surg. 67, 763.
2. Biemer, E. and Stock, W. (1983) Total thumb reconstruction: A one-stage reconstruction using an osteocutaneous forearm flap. Brit. J. Plast. Surg. 36, 52.
3. Cormack, G.C. and Lamberty B.G.H. (1984) Fasciocutaneous flap nomenclature. Plast. Reconstr. Surg. 73, 996.
4. Cormack, G.C. and Lamberty, B.G.H. (1984) A classification of fasciocutaneous flaps according to their patterns of vascularisation. Brit. J. Plast. Surg. 37, 80-87.
5. Daniel, R.K., Terzis, J. and Schwarz, G. (1975) Neurovascular free flaps. Plast. Reconstr. Surg. 56, 13.
6. Donski, P.K. and Fogdestam I. (1983) Distally based fasciocutaneous flap from the sural region. Scand. J. Plast. Reconstr. Surg. 17, 191-196.
7. Lamberty, B.G.H. (1979) The supra-clavicular axial patterned flap. Brit. J. Plast. Surg. 32, 207.
8. Soutar, D.S., Scheker, L.R., Tanner, N.S.B. and Mc Gregor, I.A. (1983) The radial forearm flap: A versatile method for intra-oral reconstruction. Brit. J. Plast. Surg. 36, 1.

Chapter 4

THE CLINICAL USES OF FASCIOCUTANEOUS FLAPS

In the early 1980's when fasciocutaneous flaps in the lower leg began to gain acceptance we demonstrated that the technique need not to be confined to the leg as some people mistakenly thought. It was not widely appreciated that the deep fascia existed to any degree outside the leg! The first part of this chapter is devoted to a description of the fasciocutaneous flaps in common use as well as new flaps many of which have been given anatomical names. For the sake of completeness I have included a variety of fasciocutaneous flaps in the arm, which nowadays have very little use even as free flaps. It is upon the flaps which are suitable for use as free flaps that recent interest has largely centred. Most of these flaps possess a constant axial vessel which is protected when the flap is raised in the plane beneath the deep fascia. The flaps have been arranged according to anatomical regions.

The second section in this chapter comprises an account of our experience with a number of fasciocutaneous flaps. Most have been used as simple local transposition flaps. Although in the axillary region and leg this experience is extensive, in the arm and elsewhere on the trunk we have not had the opportunity to use many fasciocutaneous flaps. The accounts of other's work however fill these hiatuses.

An unlimited number of flaps of various designs can be raised so that they include the deep fascia. Some people, including myself have incorporated deep fascia in Z plasties but in this work Z-plasties are not included in the series of flaps.

The section on clinical experience concentrates on the surgical technique, albeit very simple and where pertinent, specific anatomical details, indications and complications are mentioned. These latter 3 subjects are however dealt with in more detail in chapters 2 and 5.

FASCIOCUTANEOUS FLAPS IN COMMON USE.

The head and neck

In the face, the deep fascia is absent and in general the head and neck region is devoid of any surgically significant areas of deep fascia. This is no disadvantage as the blood supply of the region is so rich that simple random flaps of skin and subcutaneous tissue have on the whole proved reliable.

Mention should be made of the temporal fascia which is found between the temporalis muscle and the skin and concists of 3 layers. The first two constituting

the superficial temporal fascia, consist of a dense fibrous layer immediately beneath the skin and subcutaneous tissue of the area and a thin looser, gliding layer. Finally the densest layer of all, the true deep fascia is the layer overlying the temporalis muscle.

The 2 most superficial layers are of importance as the superficial temporal artery is intimately related to them and its importance in the use of long, thin or island hair-bearing flaps is well known. Abdul-Hassan et al. (1986) have mistakenly deprecated the deeper of those 2 layers, contending that it is lacking in substance and not in itself suitable for use as a flap.

This layer alone is of considerable use as a local flap in ear reconstruction and eyelid repair and it may be used as a free flap (Brent et al. 1985). Its great advantage is indeed its thinness and suppleness which allow it to adapt closely to the hollows and prominences of carved cartilage used for ear reconstruction.

If a fasciocutaneous flap including the temporalis fascia is to be raised, only the superficial fascia need be included in the flap. As long as the dissection skims the dense fascia over the temporalis, the superficial temporal artery will be safely preserved in the flap comprising the 2 most superficial layers.

The galea has been quite widely used for nasal reconstruction and recently as an aid to cranio-facial repair (Avelar et al. 1981, Jackson et al. 1986). The galea and the superficial temporal fascia are different names for neighbouring parts of one and the same fascial layer.

THE ARM

The upper arm

There is some confusion surrounding the nomenclature of various upper arm flaps despite the fine anatomical description of the fasciocutaneous vessels in the upper arm by Cormack and Lamberty (1984). On the basis of their injection studies they state that the skin below the deltoid area is supplied by fasciocutaneous perforators in the line of the medial and lateral intermuscular septa.

Various free flaps can be designed by making use of constant and relatively large vessels which supply the skin via such perforators. The first four flaps in this section include such vessels or are examples of flaps in which the deep fascia is the site of vessel branching prior to the skin being supplied.

1. *The deltoid flap (Russell et al. 1985)*

As its name suggests this flap overlies the deltoid muscle and is best raised deep to the deep fascia. Although the donor site is rather prominent the flap itself has the advantages of being relatively thin and deriving its blood supply via the large and constant posterior circumflex humeral artery. It can also be raised as a sensory flap if it includes the lateral brachial cutaneous nerve.

2. *The posterior arm free flap (Masquelet et al. 1985)*

This is an axial fasciocutaneous flap supplied by an unnamed artery arising from the humeral or deep humeral artery. Again because it is thin and hairless, the flap may be of particular value as a free flap and it can also be used as a sensory flap if the first cutaneous branch of the radial nerve is included in the flap.

3. *The lateral upper arm flap (middle collateral artery flap) (Cormack and Lamberty, 1984).*

This flap can be compared to the radial forearm flap as the skin is supplied by perforators from the middle collateral artery running in the lateral intermuscular septum. The main vessel is constant and is the terminal branch of the profunda brachii. The lower lateral cutaneous nerve of the arm, if included, makes it a sensory flap. There is usually some hair over this region and there may be a moderately thick layer of subcutaneous tissue in the area.

4. *The medial arm flap*

A cutaneous branch of the superior ulnar collateral artery, which emerges in the medial intermuscular septum and spreads out at the level of the deep fascia is the basis of this flap's blood supply. The flap was described by several authors in the early 1980's but was not recognised to be a fasciocutaneous flap at that time. (Dolmans et al. 1979, Kaplan et al. 1980).

5. *Random flaps*

Pedicled flaps based over the medial or lateral intermuscular septa and supplied by perforators running in the septa as described above, should be able to be safely used for local defects but there is rarely a call for such flaps as skin grafts applied to the plentiful soft tissue in the arm are the first line of repair.

Contractures of the anterior axillary fold following burns for example, have been satisfactorily corrected by an anteromedial upper arm flap. There is no clearly defined axial vessel in this flap which has been named the inner arm fasciocutaneous flap (Budo et al. 1984).

The lower arm

For all practical purposes there is only one flap worthy of detailed discussion and that is of course the radial forearm or the so-called Chinese flap (Yang 1981, Muhlbauer 1982). Lovie et al. (1984) developed the ulnar forearm flap, based on a similar principle but using the ulnar artery. It has not become popular, perhaps due to the fear of damaging the ulnar nerve.

1. *The radial forearm flap*

Initial dissatisfaction with the donor site scar was soon overcome when the potential of the Chinese flap was appreciated. A rapid proliferation of articles demonstrating its varied use followed and although the flap has been most often used as a free flap, it is also worth considering as an island flap for thumb reconstruction. In this situation one relies upon a retrograde arterial flow through the palmar arch.

The flap is a thin one and the radial artery is both constant and possessed of a large lumen, making microsurgical anastomosis simple. There are ample veins for good drainage both in the skin and accompanying the artery.

The flap is a fasciocutaneous flap and the vascular distribution in the flap exemplifies the statement of Hyrtl (1859) that arteries reach the deep fascia by way of intermuscular septa and may then terminate in the skin.

Surprisingly large areas of forearm skin (35x15 cm) can be supported on the intermuscular septal perforating vessels and bone, tendons and nerves can be incorporated in the flap. Radial forearm flaps have been used for scalp, neck and face cover, for intra-oral lining and cover of bone, for penile reconstruction (Chang 1984), oesophagus reconstruction (Harii et al. 1985), reconstruction of the hand, the correction of various contractures and the closure of lower limb defects. It is not the place of this work to give an exhaustive account of the flap's use but a list of references is appended to this section.

2. *The ulnar artery forearm flap (Lovie et al. 1984)*

It is contended by these authors that this flap is every bit as simple, safe and versatile as its radial counterpart. Moreover the donor defect, unless an inordinately large flap is used, is less obvious since the forearm is usually held in semipronation. In their series of 15 cases at least one disturbance of ulnar nerve sensory function has persisted for more than 12 months.

3. *The antecubital fasciocutaneous flap (Lamberty and Cormack 1983)*

As a result of investigating the cutaneous vascular territories of the forearm it was was concluded that the only vessel capable of supporting a fasciocutaneous flap of sufficient length to be of any real use was the inferior cubital artery, itself a branch of the radial artery. The flap was later successfully used in 2 cases (Lamberty and Cormack 1983).

It is interesting to note that in these authors' paper of 1982, the thought of using the radial or ulnar artery as the basis for a fasciocutaneous flap completely eluded their minds. Such is the state of our sophisticated education that we sometimes still do not see the wood for the trees and in this case it was left to the Chinese to emerge triumphant from the forest!

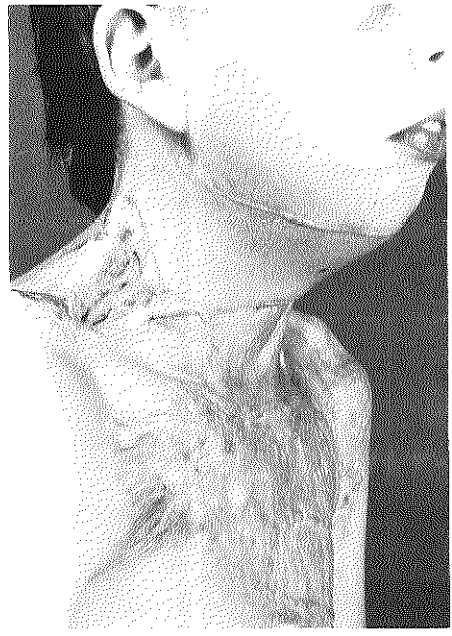
THE TRUNK

Axial fasciocutaneous flaps

1. *The Supraclavicular axial pattern flap (Lamberty, 1979)*

In the period when axial pattern flaps were all the rage, this flap was one of the examples which emerged from the intensive search for new axial flaps. It is not strictly a fasciocutaneous flap as deep fascia is only present over the trapezius but the whole flap is best raised in this plane. The flap is raised from the upper surface of the shoulder and based on the neck where a superficial branch of the superficial transverse cervical artery usually enters the flap between the skin and the platysma.

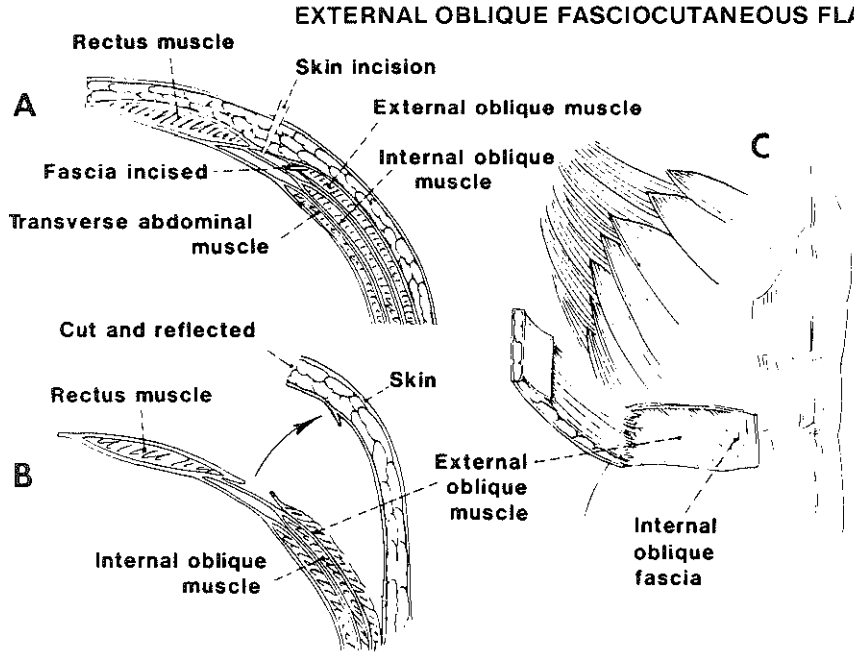
The vessel is relatively constant and runs laterally towards the acromio-clavicular joint where it divides into 2 branches. It supports admirabley what is in effect an epaulette flap, which has been used by Lamberty and this author with success. Its main disadvantage is the ugly donor site and contracted skin grafts in this area may prove very annoying. Although it is a sound flap for correcting neck contractures (Fig. 4,1) nowadays other alternatives should be explored first.



4.1 Supraclavicular flap. Note donor scar on shoulder.

2. *The External Oblique Fasciocutaneous Flap (Fisher, 1985)*

Fisher has described this flap clearly and its use was restricted to covering recalcitrant elbow defects. Its anatomical position makes it particularly suitable for such problems but by extending the length of the flap slightly it is possible to use it for the neighbouring upper arm and forearm. One other possibility worth bearing in mind is the use of a posteriorly based external oblique fasciocutaneous flap for the contralateral hand. It is well suited to augment the first web space for example and the arm lies quite comfortabley across the abdomen during the period before the base is divided.
The flap design and anatomy is shown in figure 4,2.



(A) Cross-sectional diagram showing the level of the incision for developing the medial margin of the flap in the external oblique fascia.
(B) Elevation of the external oblique fascia off the underlying muscle.
(C) Neurovascular pedicles enter the fascia along the lateral abdominal wall.

(With the kind permission of Dr. J. Fisher. PRS 1985)

4.2 External oblique fasciocutaneous flap.

3. *The inferior epigastric fasciocutaneous flap*

The superficial epigastric vessels which one divides when raising a groin flap, are the axial vessels in this flap and they run superficial to the deep fascia over the rectus abdominis.

A vertical flap may prove more useful than the groin flap in some situations and this fasciocutaneous flap is particularly suitable for the repair of hernias in the lower lateral abdominal wall.

4. *The delto-pectoral flap*

This is anatomically a fasciocutaneous flap although, like the previous flap, it will probably survive even if the deep fascia overlying the pectoralis major is not included in the flap. Both Bakamjian and Mc Gregor recommend that the fascia is included as the vessels are protected when one dissects in the deeper plane.

Random fasciocutaneous flaps

1. *The posterior thoracic flap*

After 5 years of experience with this flap it is possible to say that both for the patient and surgeon it has proved a very gratifying and reliable flap for the correction of axillary contractures.

Cormack and Lamberty drew attention to the fact that the parascapular artery if included in this flap is probably largely responsible for the good vascularisation but this subject has been more fully dealt with in Chapter 3.

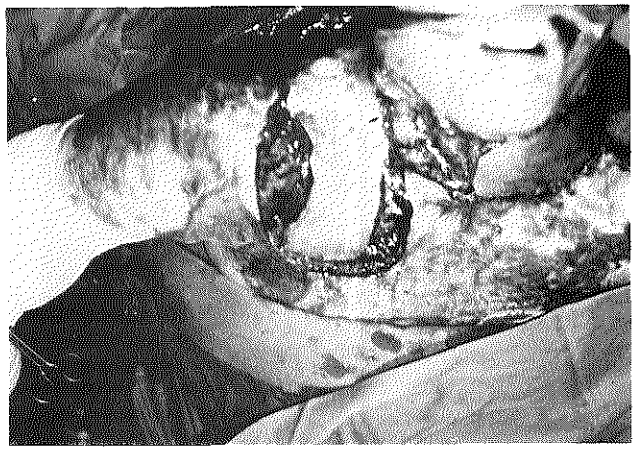
2. *Anterior thoracic flaps*

A vertically disposed fasciocutaneous flap overlying the pectoralis major has been successfully used as an adjunct to an epaulette flap for correction of a neck contracture. One would be loath to use such a flap in a virgin chest but an example is shown in this chapter where the chest was already grafted and scarred (fig. 4.3).

In theory a considerable number of random fasciocutaneous flaps can be raised on the trunk. The proportions of the flaps should probably be limited to a 3 to 1 length to width ratio initially where no axial vessel is known to supply an area of skin.

Flaps over the trapezius muscle may be of use in posteroinferior neck defects and transverse thoraco-epigastric flaps (Bohmert, 1980) have already proved of great value in breast reconstruction.

Although in the era of free flap surgery it may be considered "old fashioned" to use a distant flap for reconstruction (e.g. groin flap for hand defects), the safety and simplicity of this technique has much to commend it. Posteriorly



4.3 Anterior thoracic flap for neck contracture.

based thoracic flaps situated just inferior to the axilla would seem very suitable for thumb cover. A fasciocutaneous flap in this area will usually be thin and the donor site is cosmetically superior to an anterior thoracic flap. Perforating vessels similar to those described by Fisher (1985) are present in the mid-axillary line and will help support such flaps.

Vasconez (1986) has used fasciocutaneous flaps overlying the gluteus maximus, in a V-Y configuration to close midline sacral defects. In the perineal area fasciocutaneous flaps with a 4 to 1 ratio have been used by us to reconstruct the vulva. These have extended vertically onto the upper, inner thigh. Recently Wee (1986) has demonstrated axial vessels originating from the pudental artery running parallel to the labia and flaps based on these vessels have be used for vaginal reconstruction.

THE LEG

The lower leg

This region was the first in which the fasciocutaneous flap proved of great value. A rebirth of enthusiasm for simple local flaps in the leg developed and continues as a result of the fasciocutaneous flap's reliability. The characteristics of random fasciocutaneous flaps in the leg have been the centre of interest since, certainly in the lower leg, there appear to be scarcely any axial vessels of substance.

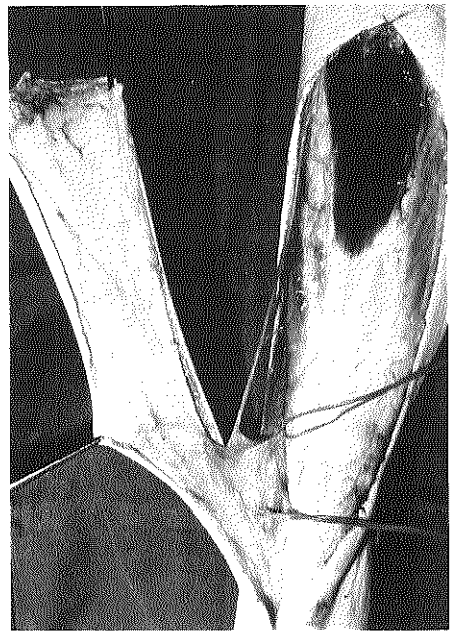
Perhaps the best and most complete description of the blood supply and the potential of fasciocutaneous flaps in the lower leg is that of Casey (1986). He attributes the safety and success of these flaps to the longitudinal orientation of vessels at the level of the deep fascia which anastomose freely with each other and derive a sound perfusion via the base of the flap. Here not only the fascial plexuses and their branches but also the intact musculo-cutaneous perforators and their branches contribute to the longitudinally oriented blood flow. No mention is made by Casey of specific axial vessels in the lower leg. Proximally musculo-cutaneous perforators are prevalent whilst distally the fascial plexuses and their perforators become steadily more and more dominant.

By confining the length to breadth ratio of flaps to 3 to 1 in the leg and designing the flaps so that they parallel the long axis of the limb one can expect few problems. Haertsch (1981) on the basis of injection studies, favours postero-medial flaps but Casey has also described posterior, lateral (lying over the fibula) and medial flaps which he contends are reliable.

In addition bipedicled and distally based fasciocutaneous flaps have been employed (Fig. 4,4). In the case of the latter one should keep the length of the flap as short as possible and it is essential to preserve the 2 prominent perforating arteries running in the intermuscular septum medial to the Achilles tendon. These vessels are branches of the posterior tibial artery.

Distally based flaps have proved of great value in resurfacing defects around the heel and ankle. A two stage procedure is usually necessary and the pedicle is returned to the donor site at the second stage. (Donski et al. 1983).

Alternative flaps in this region have a more limited arc of rotation. The lateral calcaneal artery flap (Grabb et al., 1981) itself an axial flap raised deep to



4.4 Distally based fasciocutaneous flap lower leg.

the deep fascia which is virtually non-existent at this level, is very safe and is particularly suitable for relatively small defects over the Achilles tendon. It can also be raised as an island flap (Holmes et al. 1984).

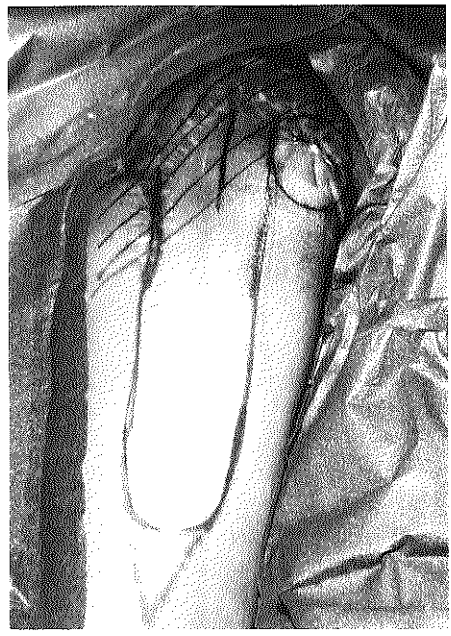
On the foot sole, the plantar fascia can be included in flaps based on the medial or lateral plantar vessels. These fasciocutaneous flaps are of use in closing defects on the postero-plantar area of the heel.

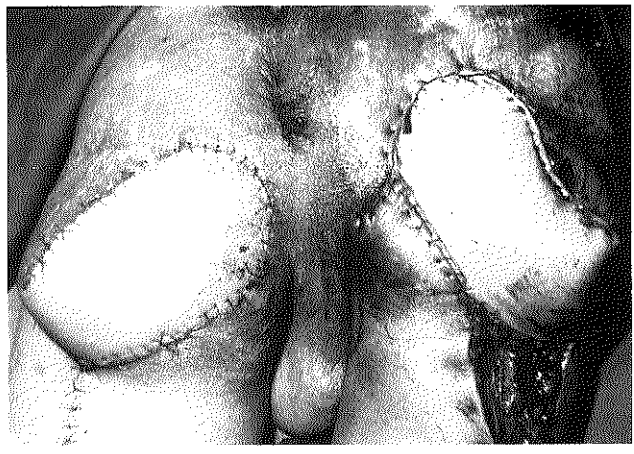
These 3 last named flaps are relatively simple to design, dissect and set into place and for these reasons have obvious advantages over free flaps.

The thigh

Because of the very large bulk of muscle protecting the femur and lower parts of the pelvis there is less of a demand for fasciocutaneous flaps in these areas. Distally based flaps in the lower thigh have been used for defects round the knee joint but deep defects are best closed with gastrocnemius flaps.

One flap which is useful in the ischial region is the posterior thigh flap based on an axial branch of the inferior gluteal artery. (Fig. 4,5). It can be of value in recurrent pressure sores overlying the ischial tuberosity and as a rule the donor site can be closed by direct suture.





4.5 Posterior thigh flap.

The tensor fasciae latae flap is frequently extended inferiorly to include the fascia lata and although a pure fasciocutaneous flap based on the fascia lata has been used, it is as a rule better to include the muscle, as the arc of rotation is considerabley enlarged by so doing. T.F.L. flaps measuring 30 x 15 cms. and principally composed of a fasciocutaneous element have proved very helpful in the repair of large ventral hernias.

The principle of extending a musculocutaneous flap distal to the muscle but including, in its place an area of deep fascia, dates back to Mc Craw's article on the "Versatile gastrocnemius flap" (Mc Craw et al. 1978). Here it was stated that medial gastrocnemius musculocutaneous flaps could carry skin down to a point 5 cm proximal to the medial malleolus and lateral gastrocnemius flaps to a point 10 cm above the lateral malleolus. It has since been shown that it is not necessary to raise muscle but only the deep fascia in the whole of these flaps (Tolhurst et al. 1983).

The same principle has been applied in the pectoral muscle "paddle flap" where the extended area of skin is carried on a piece of anterior rectus sheath (Mc Craw et al. 1986). An extended T.F.L. flap may be designed in the same way as an extended gastrocnemius flap but T.F.L. has been also used as a musculo-fascial flap in 2 cases to repair an abdominal hernia (Nahai et al. 1979). Care must be taken to include the vascular pedicle to the muscle in the flap and it is possible to transpose the musculofascial unit on the vessels alone.

Table 4.1. Fasciocutaneous flaps used over 8 year period.

Site	Number	Type	
Lower leg	25		
Thigh, Buttock	22	(6 for vulva)	
Trunk (excluding delto-pectoral flap)	28	Posterior thoracic flap	23
		Anterior thoracic flap	1
		Lateral thoracic flap	2
		Shoulder flap	2
Arm (excluding radial forearm flaps)	5		
Abdomen	1		
Total	81		

CLINICAL EXPERIENCE

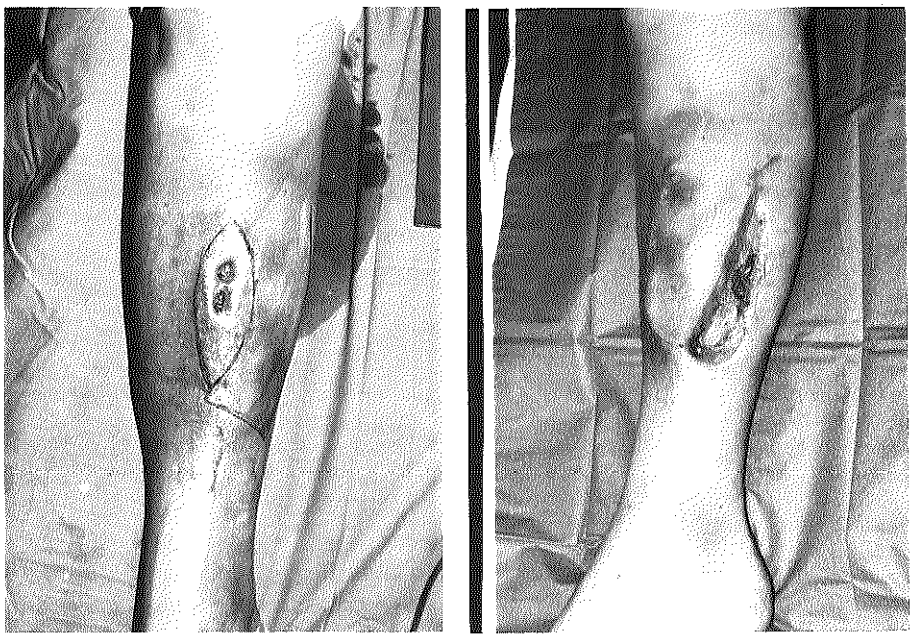
The lower leg

In one British plastic surgery centre at least, it has been the practice of most surgeons to include the deep fascia in cross-leg flaps. When I was training at East Grinstead almost 20 years ago this idea was already firmly ingrained in the department but no one seemed to know who had first proposed it. I certainly

had raised several fasciocutaneous flaps at that time but there was no discussion about the vessels associated with the deep fascia and in fact probably no real appreciation of the exact value of the deep fascia. It was merely considered safer.

About 5 years after this period, Bowen et al. (1974) described a series of delayed local leg flaps which included the deep fascia. They too made no mention of the vessels related to the fascia and indeed simply mentioned in passing that it was their practice to "raise deep fascia with the flap".

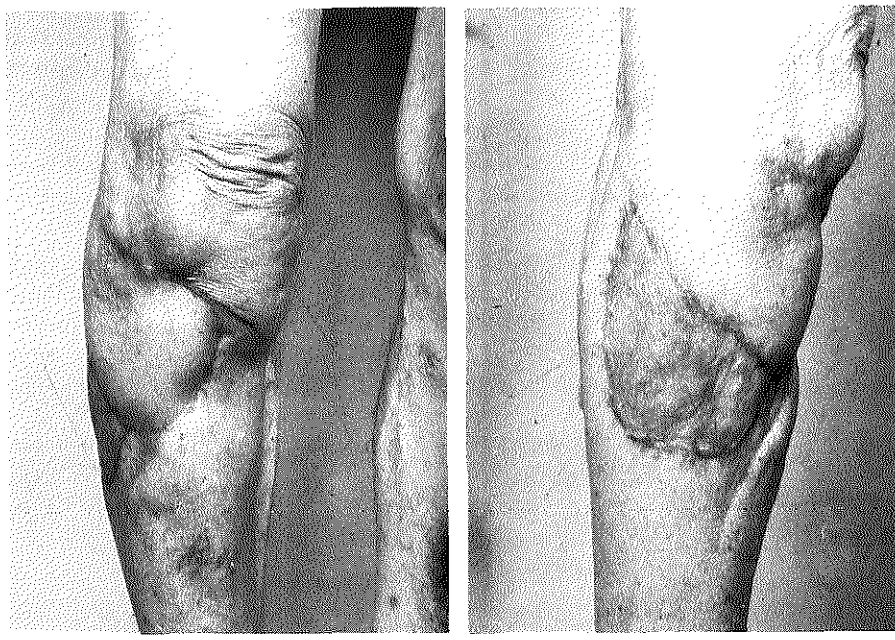
Undoubtedly others had included the deep fascia in various flaps in the leg but, as is well known, it was Pontén's substantial experience with fasciocutaneous flaps that put the technique "on the map". Our inital use of fasciocutaneous flaps was confined to the lower leg and of the first 3 cases two flaps were used to cover exposed anterior tibia in the lower half of the leg (fig. 4.6). The



4.6 First simple fasciocutaneous flap lower leg.

third case was in some measure an advance because a flap was used for proximal tibial coverage and this area had not been previously treated with a fasciocutaneous flap (fig. 4.7). It marked our understanding that the deep fascia, although very well developed in the lower leg, was certainly present more proximally.

A large amount of information is available on the clinical experience with fasciocutaneous flaps in the lower leg. Besides Pontén's first report on these flaps (1981), Barclay et al. (1982) and Casey (1984) have together given details



4.7 Fasciocutaneous flap inferior to knee.

of more than 60 cases. We have used 25 fasciocutaneous flaps in the lower leg, the majority of which were employed to cover exposed cortical bone.

Our experience will be described and as far as possible the different flaps used will be dealt with under the 3 main types described by Casey (1986).

Medial proximally based flaps

These flaps are most commonly called upon as they are conveniently situated to transpose over exposed tibial bone. The subcutaneous border and surface of the tibia are the most vulnerable areas because they are protected by a minimum of tissue.

Thorough excision of the wound edges is planned by marking out the area of soft tissue to be excised. The defect can then be visualised and the fasciocutaneous flap required for cover is drawn on the medial surface of the leg with its base situated proximally and the long axis of the flap parallel to the long axis of the leg. If a satisfactory flap can be designed so that it includes no dense scar, indurated or pigmented tissue the medial flap is prefered because of its superior vascularity and proximity to the defect.

It is advisable to design the flap so that its width exceeds the width of the defect by 3 to 4 cm. This allows the flap to fall comfortabley into a shallow

defect if this is present. On the whole deep bone defects are better covered with muscle flaps. The extra width also ensures that a good 2 or 3 layer closure by suture to the soft tissues surrounding the defect is readily accomplished.

In most cases where a medial flap has been used in the lower leg a 3:1 length to breadth flap has been designed and the measurements of these flaps have frequently been of the 21:7 cm. order. Since the flaps are being transposed anteriorly over a convex surface (the cross section of the lower leg being roughly circular) it is necessary to design the flap 3 or 4 cm. longer than the defect in order to prevent an embarrassing short fall once the flap is transposed.

I prefer to operate without tourniquet as the vascularity of the tissues can be more readily judged. The edges of the flap are incised to the deep fascial plane and the incision deepened through the fascia. Dissection of the flap is best begun distally. The flap is raised from the muscle and I prefer to include the deep plexus with the flap, where this is present. As it is freed a few sutures between the fascia and skin are inserted to keep the fascia in contact with the subcutaneous tissue.

Haemostasis is not difficult as a rule and it is thus not necessary to use drains under the flap. Drains are not a sine qua non of flap surgery - they are only indicated here when haemostasis is inadequate. At this stage fluorescein can be injected to test the viability of the flap. The flap is then transposed to the defect and suturing begun. Two layers of sutures are used; the first fixes the fascia to the soft tissue of the wound defect and the second closes the skin.

A few tacking sutures between the deep fascia and the underlying soft tissue help to prevent dead space and fluid accumulation. Once the flap is sutured in place a split skin graft is removed from the opposite inner thigh, trimmed to size and sutured or stapled to the edges of the donor site. If a tieover dressing is deemed advisable it can be rapidly fixed by the technique described by Tolhurst et al. (1986) using staples. As a rule I have found a simple dressing of tulle gras, guaze and wool over the skin graft, held in place with a snug bandage, perfectly satisfactory.

The axiality of the fascial plexus in these flaps parallels the long axis of the leg. Moreover terminal branches of an extension of the saphenous artery boost the blood supply to these flaps so that they have on the whole been reliable. In only one case was a large part of a flap lost (see Chapter 5). There were no faults in design but the skin was fibrotic, pigmented and when incised revealed venous stasis and thus it was the tissue itself which was unsuited for use as a flap.

In one case a bipedicled flap was used to cover a defect exposing bone on the dorsum of the foot (fig. 4,8). This technique was chosen as the patient was a child and fixation and positioning were rendered extremely simple by suturing the edges of the flap to the margins of the foot defect. The flap was divided after 3 weeks and healed without complications.

4.8 Bipedicled fasciocutaneous flap for dorsum of foot.

Lateral and antero-lateral proximally based flaps

These flaps are well suited to defects on the anterior margin or leading edge of the tibia. Although Casey describes these 2 flaps separately I prefer to deal with them together as they are basicly raised from the same broad area. The same principles as described in the previous section relating to the excision and design of the flap apply. The flap when raised exposes the tibialis anterior muscle anteriorly and the peronei posteriorly. All accept a skin graft well.

There are 2 main objections to the use of flaps in this area. In the first place the scars and the grafted donor site are more readily seen on the outside of the leg and especially in women constitute a cosmetic disadvantage. Secondly there is no vessel equivalent to the saphenous artery on this side of the leg and even though the fascial plexus is longitudinally oriented, it is thought that the viability of these flaps, on theoretical grounds at least, may be questionable. Smaller flaps measuring 8 x 3 cm. for example have proved reliable. One larger flap (23 x 7 cm.) was raised on the lateral side of the leg but again in pigmented and indurated skin. Venous stasis was encountered as the dissection proceded. In this patient the bone was chronicly infected and widely debrided, leaving a deep trough into which bone chips were put. The fasciocutaneous flap was then transposed over the area and the flap sutured in position. The distal half

of the flap became necrotic and was lost resulting in concomitant loss of the bone chips and re-exposure of bone. Some of the deep fascia appeared to survive and granulation tissue rapidly developed which enabled a split skin graft to be applied, ultimately leaving a small area of bone (1 x 1,5 cm.) exposed.

In line with the policy of delaying bone reconstruction in acute injuries until good soft tissue cover has been achieved, I now feel that bone chips or grafts should only be inserted after a fasciocutaneous flap has healed primarily. The reason for this is that one hopes for more rapid healing when 2 vascularised areas are in contact. Although debrided bone is less vascular than a fasciocutaneous flap, there are nevertheless reasonable blood vessels present if enough sclerotic bone has been removed.

Thus this major complication was caused not only by designing the flap in a poorly vascularised area, where venous stasis existed, but also by inserting a layer of avascular bone chips between the bone and the flap. If flaps from the posterolateral area are used there is usually a significant area of skin between the exposed bone antero-medially and the flap. Transposing the flap across this skin as a one stage procedure means that a large area of skin must be excised. Obviously the closer to the defect that the skin flap can be designed the better.

More proximally situated flaps

The deep fascia just distal and medial to the knee is less well developed than further distally. Laterally however the fascia over the origin of the tibialis anterior and extensor digitorum muscles is very thick and more difficult to dissect from the underlying muscles.

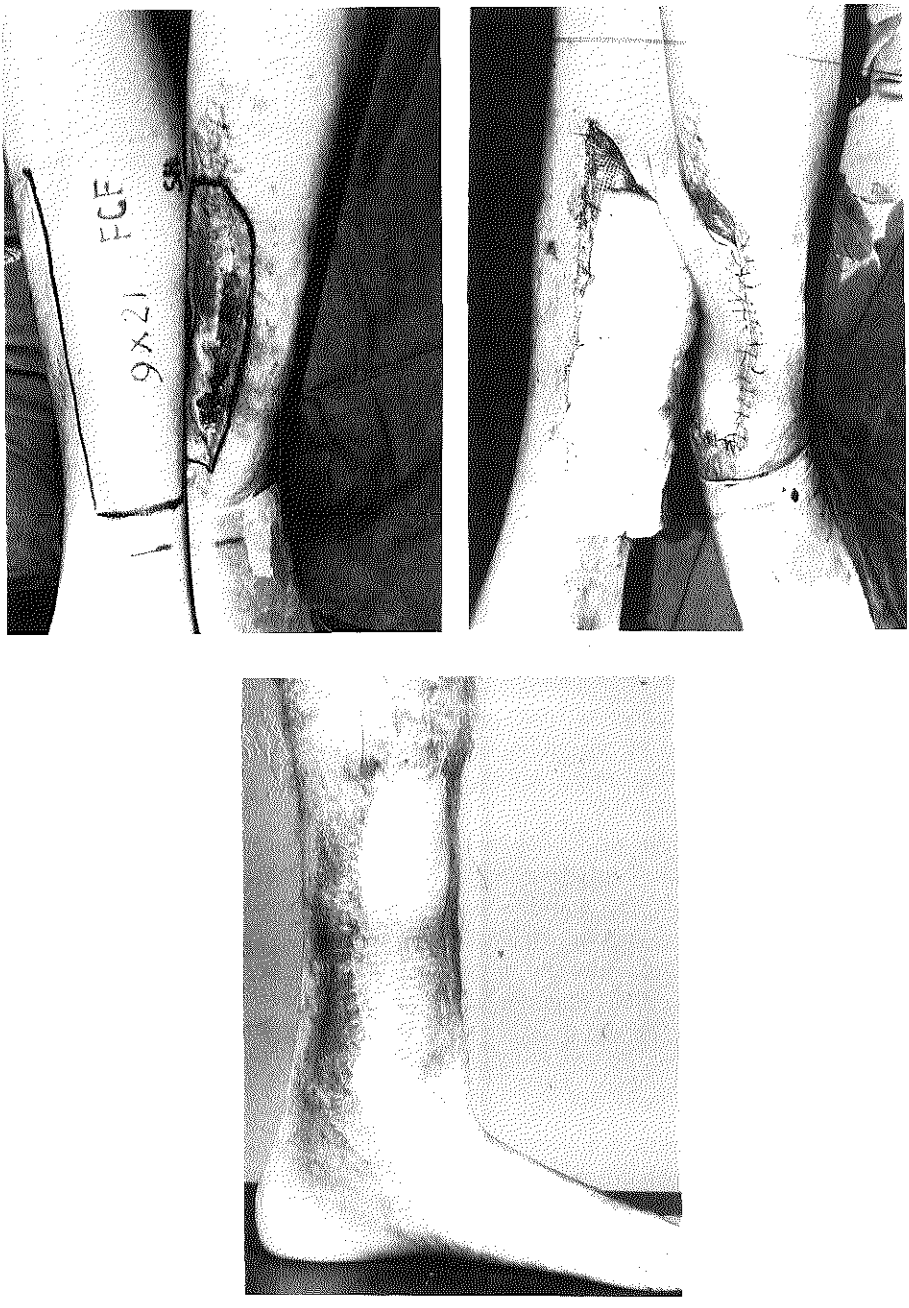
Fasciocutaneous flaps with a 3:1 ratio have proved satisfactory when situated medially. No proximal flaps have been used on the lateral side of the leg and if these are to be employed one should not overlook the superficial part of the common peroneal nerve. Dissections have demonstrated that the plane between the lateral fascia and the muscle is more difficult to establish but there is no reason why these flaps may not be used.

Posterior proximally based flaps

These flaps can be raised over the calf and are principally of value for use as cross leg flaps as will be clarified in the following section.

Cross-leg flaps. (fig. 4,9)

If for any reason it is decided to employ a cross-leg flap, the deep fascia should be included in the flap. This has certainly been the practice in some centres for many years. The flaps can nowadays be designed longer than previously



4.9 Cross-leg fasciocutaneous flap.

and if possible, medially situated or posterolateral flaps are preferable to horizontally disposed flaps. This is because of the axiality of the fascial plexus and the end branches of the saphenous artery medially.

The choice of flap will depend on the acceptor site. Since this is usually over the tibial bone, a medial or posterior flap is suitable. The latter is very well vascularised even though it is necessary to divide the connection between the intermuscular septum posteriorly and the deep fascia. 4:1 flaps in healthy skin in this area can be expected to survive.

The flaps are raised in the same manner as already described, taking care to design the flap so that it will fit the defect comfortabley and also so that the skin bridge will not be unduly taught or twisted.

The donor site is first grafted and the flap then sutured to the acceptor defect in 2 layers as already described. Fixation with external metal appliances is preferable to plaster of Paris and is completed once the flap is sutured in place.

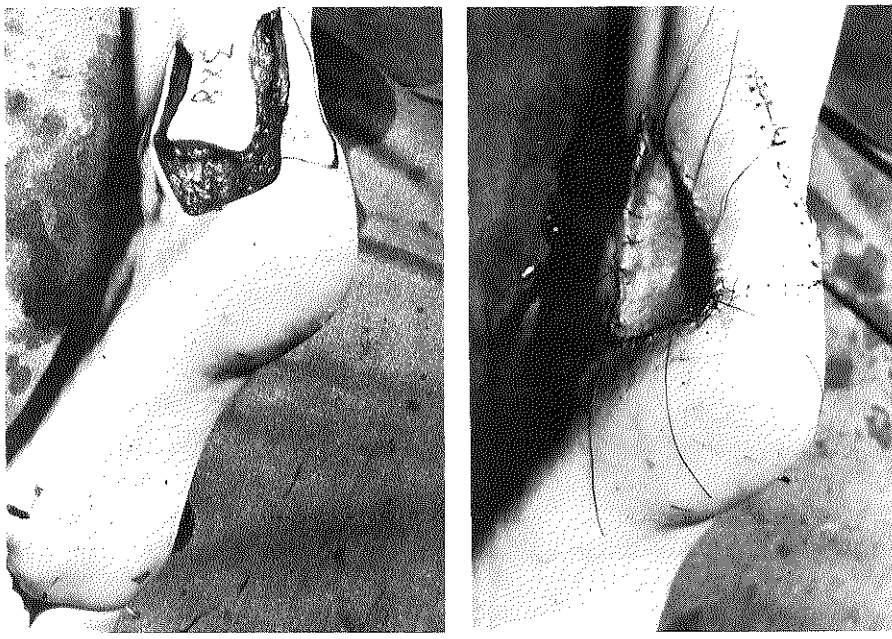
2 medial flaps and one more posteriorly situated flap have all done well and division and insetting of the flaps at 3 weeks have been uneventful. Further salient points differ in no way from those in the plethora of articles describing experience with this technique (Jayes 1950, Morris et al. 1978).

Nowadays with the increasing availability of free flap surgery, cross-leg flaps are less frequently indicated. The major objections to the technique are firstly the lengthy, cumbersome and costly fixation and secondly the fact that the flap itself ultimately introduces no new blood supply to the area. It is, once divided, in fact parasitic. This is far from ideal in an area where one is often faced with poorly vascularised or potentially infected bone. Cross-leg muscle and musculocutaneous flaps are obviously no better.

Lateral calcaneal artery flaps

9 lateral calcaneal artery flaps (fig. 4,10) have been used in our department but only 3 included in this series. Although the artery is largely responsible for the reliability of this flap, it has been raised to include deep fascia, albeit very indistinct at this level. I am not suggesting that the fascia contributes directly to the vascularity but its inclusion underlines the protective value of the deep fascia when an axial vessel situated superficial to the deep fascia is to be used as the main source of the flap's blood supply.

The deep fascia is continuous with the retinacular ligaments of the ankle and thereafter becomes virtually non-existent. Some deep fascia above the ankle may be included in long flaps. It is possible to continue the dissection (which does not include the retinacular ligaments) distally to the ligaments in the same or a slightly deeper plane. If these flaps are similar in size to that shown in fig. 4,10 one can hardly justify including them as fasciocutaneous flaps and this is why only 3 have been included in this series.



4.10 Lateral calcaneal artery flap.

The thigh

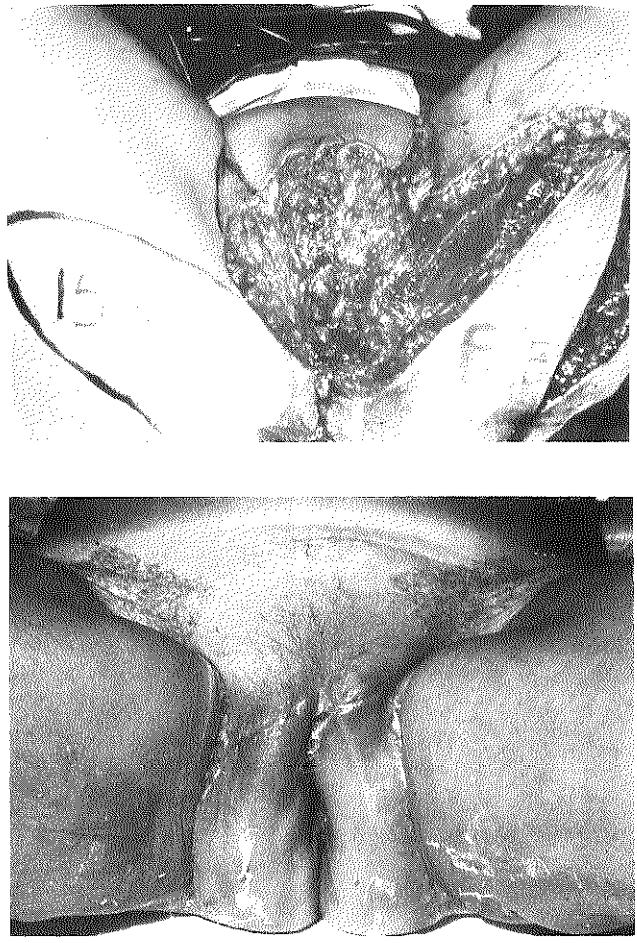
Shortly after our initial experience in the lower leg, use was made of fasciocutaneous flaps in the thigh but there were still many finer points relating to the precise vascularisation of these flaps which were to be unravelled. For example as more cadaver dissections were performed, many small axial vessels were described and named, quite justifiabley as they contributed in no small measure to the safety of the flaps.

Flaps raised over the gluteal region have for the sake of simplicity been included with the thigh but will be separately described.

The medial thigh flap

Medially situated fasciocutaneous flaps have been most commonly used for such problems as vulval defects following radical excision for carcinoma and also for vaginal corrections. Musculocutaneous flaps containing the gracilis muscle have been used for vaginal reconstruction (Mc Craw et al., 1976) and also for reconstruction of the vulva following radical excision. Such flaps are known to be somewhat unreliable and pure gracilis muscle flaps are safer. Gracilis musculocutaneous flaps have been used by us for vulval reconstruction but a

number of complications including partial muscle or skin and fat necrosis and persistant fistulae were encountered. The flaps were in addition too bulky and tended to sag inferiorly. As an alternative, fasciocutaneous flaps raised from the medial aspect of the thigh have proved reasonabley satisfactory (fig. 4,11).



4.11 Medial thigh fasciocutaneous flap for vulval reconstruction.

Vertical transposition flaps

In all 9 of these flaps have been raised from the upper medial thigh, 4 of which also proved satisfactory for widening of the introitus.

The surgical technique differs in no way from that described in detail in the lower leg section. It is possible to transpose these flaps through almost 180°.

The donor sites have all been closed primarily. Unfortunately the quality of the scar on the upper medial thigh is poor. It tends to stretch considerably with time and is frequently apt to be dark purple in colour.

Patients requiring vulvectomy may be of advanced age and the presence of atherosclerosis and diabetes should not be overlooked. These diseases are notorious for compromising the circulation in the lower leg and even in the thigh may be responsible for flap necrosis if 3:1 vertical flaps are used. Depending on the severity of the disease and the size of the defect longitudinal fasciocutaneous flaps must be very carefully considered. The flap is technically so simple to use that inexperienced or poorly qualified surgeons from other specialties have been tempted to try them in unsuitable cases with disasterous results.

Gluteal flaps

7 rotation flaps and 2 V-Y fasciocutaneous flaps have been used over the buttock. The fascia is thin but distinct and easily dissected from the gluteus maximus. There has been no loss of any portion of these flaps and in all cases primary closure was achieved with no recourse to skin grafts being needed.

Rotation flaps are on the whole reliable and have been popular in the buttock for decubitus defects. The inclusion of the deep fascia in our cases has made the operation in no way more difficult. In some cases we have taken a separate gluteus maximus muscle flap and transposed it to fill a deep defect following removal of the ischial tuberosity. The fasciocutaneous flap has then been rotated over the muscle and the whole wound sutured.

V-Y musculocutaneous flaps including the gluteus maximus have become popular for the closure of large sacral defects. Frequently flaps from both sides of the midline defect are needed. If however the defect is wholey or partly superficial it is possible to use a V-Y fasciocutaneous flap which relies on muscle perforators from the gluteal arteries. Dissection in the region of these vessels, that is to say in the centre of the flap should be limited. The medial and lateral extremities of the flap can be thoroughly freed from the muscle but superiorly and inferiorly one should begin with a cautious 2 to 3 cm. undermining until enough mobility is present to allow flap sliding and easy closure of the defect. If this cannot be achieved it may be wiser to free the muscle over a corresponding area as a V-Y flap.

The posterior thigh flap (fig. 4,5)

This flap has proved especially useful for the closure of recurrent defects around the lower gluteal and ischial region. Unfortunately pressure sores have a tendency to recur and repeated attempts to close them with flaps which sometimes become partially necrotic can leave badly scarred areas which may defy the inventiveness of plastic surgeons. In the last 10 years with the introduction

of musculocutaneous and fasciocutaneous flaps new solutions have been introduced.

As a last resort we have found the posterior thigh fasciocutaneous flap very helpful in this situation. It is designed as a vertical flap with the base at the level of the gluteal crease. The whole length of the upper thigh skin is usually not needed but a 3:1 flap suffices for ischial cover.

The flap depends for its success on the terminal branch of the inferior gluteal artery which can be demonstrated with arteriography in a severely scarred area. As in the case of other leg flaps, the dissection is simple and is readily accomplished if one raises the flap from the muscle, beginning inferiorly. Depending on the width of the flap and the tissue laxity, primary closure of the donor site is sometimes possible.

The flap has to be transposed more than 90° to reach its destination but this too presents no problem due to its relative thinness and suppleness. Three flaps have been used for recurrent ischial defects with success.

Random thigh flaps

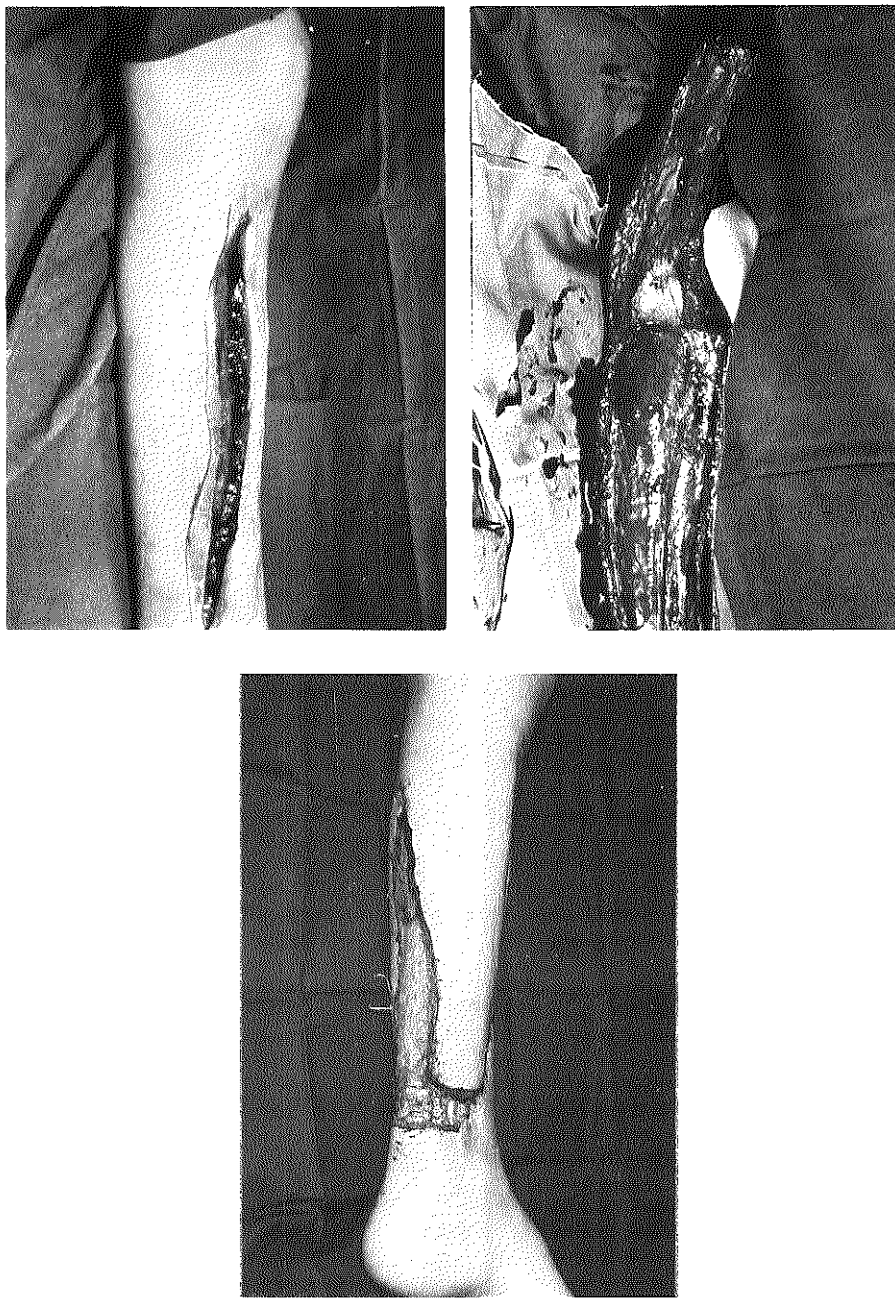
It is possible to design a large numer of other random fasciocutaneous flaps on the thigh. We have used only 2 transposition flaps on the posterolateral thigh but have also often included the deep fascia in Z plasty flaps on the thigh for correction of burn scars. This probably does not confer a great deal of benefit to the Z plasty as most ordinary Z plasties survive and the deep fascia renders relatively short flaps slightly less supple.

Discussion

In total over the last 8 years, 47 fasciocutaneous flaps have been used in the leg; 25 were for lower leg defects and 22 for the thigh, buttock or vulva. The lower leg flaps have thus been slightly more commonly used and have varied in size from relatively small flaps to the occasional daringly long flap (fig. 4,12). Most have been longitudinally oriented, certainly since the significance of axiality in these flaps was appreciated.

In the thigh because of the large bulk of muscle covering the femur there is less of a need for flaps, as split skin grafts will usually suffice. Distally based flaps in the lower leg or thigh have not been used in our department although others have reported success with both types of flap.

It should be again stressed that the fasciocutaneous flap is not suitable for all leg defects. As a rule it is particularly suitable for acute, relatively clean wounds or for skin defects exposing cortical bone which is not the seat of chronic osteomyelitis. Initially we used some fasciocutaneous flaps in such cases, fortunately with success in all but two patients but nowadays muscle flaps are deemed preferable, not only because the deep defects in bone left following



4.12 Long fasciocutaneous flap to cover exposed tibia.

proper debridement can be filled better with bulky muscle but also because we believe that the superiority of muscle flaps over fasciocutaneous flaps (Calderon et al. 1985) was not totally convincing. The article describing the experiments was discussed by Robson (1985) who pointed out the defects of the study and suggested an alternative flap model. More recently Fisher et al. (1987) proved conclusively in an experimetal study that musculocutaneous flaps were far better than skin flaps for bone cover. By isolating all but one area of bone which was then covered with a flap, it was possible to show that good revascularisation of the bone developed under most of the musculocutaneous flaps but under only 3 of 17 skin flaps.

The trunk

The deep fascia over the thoracic muscles is much thinner than that found in the leg and this is supposedly to allow ease of chest expansion with respiration. Nevertheless most muscles are covered with a layer of fascia which has a superficial and sometimes a deep vascular plexus related to it. The pectoralis major and latissimus dorsi muscles are very well suited to closing sizable defects of the trunk, especially where bone or deep defects need soft tissue cover.

Fasciocutaneous flaps, being on the whole much thinner than muscle or musculocutaneous flaps are particularly suitable when skin replacement only is required. In most cases split skin grafts will suffice but where the expected contracture of the graft will limit function, a skin or fasciocutaneous flap is indicated.

Shortly after we had begun to confirm the reliability and value of fasciocutaneous flaps in the leg, it occurred to me that if the deep fascia was present elsewhere, it should be possible to use the principle in such regions. The frequently recurring problem of the axillary contracture following burns seemed to lend itself to flap correction as skin grafting can be most unsatisfactory. There is usually a good take of the graft, as part at least is laid directly on muscle. But unless the arm is kept in abduction for three months with a cumbersome splint, some degree of recurrence of the contracture is inevitable and a repeat procedure is often required.

If the graft does not take a prolonged and frustrating period ensues. Not only is the shoulder joint difficult and uncomfortable to immobilise, but the granulating area in the axilla can prove, like areas in the back, exasperatingly resistant to further skin-grafts.

In an initial series of 15 patients, 3 to 1 fasciocutaneous flaps were raised from the postero-lateral chest and transposed to the axilla following release of the contracture (fig. 4,13). In 2 cases only was there any loss of tissue but both were insignificant and healing occurred rapidly without functional impairment. This experience was reported by Tolhurst et al. (1982) and initially attracted the criticism that there was no deep fascia on the trunk! Since then the criticism had been retracted as those responsible realised their anatomical inadequacies.

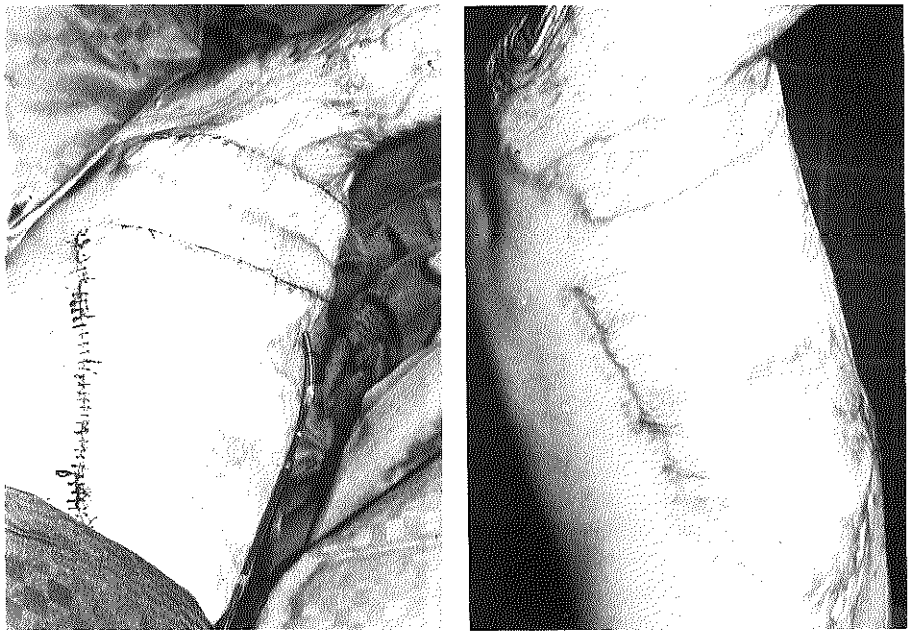
4.13 Posterior thoracic flap for axillary contracture.

The surgical procedure broadly follows the same pattern as that outlined in the section on the lower leg. The axillary contracture is first released and any irregular pitted skin and dense scar excised. The defect is then measured and a suitable transposition flap designed adjacent to the posterior extremity of the defect.

The flap is raised from the underlying muscles, beginning distally and any septa which are connected to the deep fascia are divided. The flap is transposed to the defect and sutured in layers. The donor site can be closed primarily in adults if the flap is not more than 8 cm. broad but wide undermining of the adjacent skin is necessary. If primary closure is impossible a split skin graft is applied to the donor site.

One of the great advantages of this technique is that the patient can begin to move his shoulder joint within a week of the operation and no abduction splint is required. The other advantages are described in our paper which also included the first description in English of the modern concept of the blood supply of the skin. This has since been amplified and clarified in this work. (Chapter 2).

It was in this series that this concept of the blood supply to the skin was strengthened by the demonstration that fasciocutaneous flaps containing areas of skin graft survived in toto (fig. 4,14).



4.14 Long posterior thoracic fasciocutaneous flap. Half of flap is raised in old skin grafted area.

Other thoracic flaps

Although most of our fasciocutaneous flaps on the trunk have been used for the axilla, we have used one anterior and vertically disposed thoracic flap for a neck contracture (fig. 4,3) and 2 shoulder flaps for the same problem.

The disadvantage of the shoulder flap is the split skin graft at the donor site. If the graft does not take well ugly scars may develop which are difficult to improve.

The vertical anterior chest flap is only indicated when the chest is scarred. A virgin chest, be it male or female, should not be used as a flap donor site if other reasonable alternatives are available.

Various other small flaps, excluding delto-pectoral flaps, have been used for local chest defects and to cover upper arm stump defects (Tolhurst et al. 1982).

The arm

Our experience has been very small, largely because flaps are rarely needed in the arm due to the bulk of muscle tissue present. In most defects split skin grafts achieve adequate closure. One extended lateral upper arm flap was used in a drug addict (see Chapter 5) and an inner arm flap for an anterior axillary contracture.

As this work is primarily based on clinical experience which proceeded the advent of the radial forearm flap, a description of the advantages of this flap is not included in this section.

Occasional local random fasciocutaneous flaps have been used for closure of small defects in the arm with success.

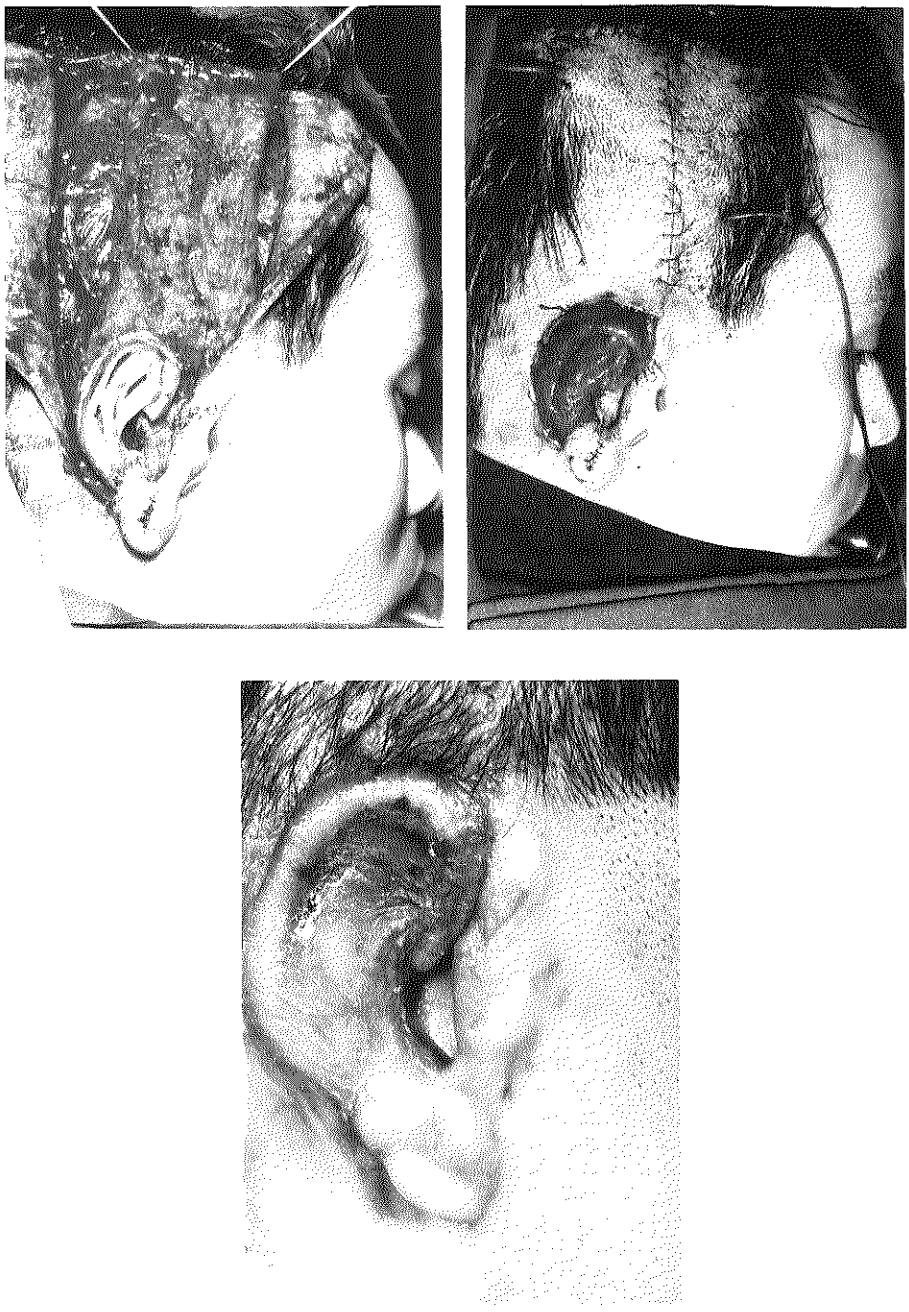
The disadvantages of the inner arm flap have been described in the first section of this chapter.

The head and neck

Because of the rich blood supply in the head and neck and the relative lack of fascia, most flaps do not fall into the category of fasciocutaneous flaps. 14 local flaps comprising pure fascia and largely vascularised by the superficial temporal artery have been used with success. Of these, 13 were for ear and one for upper eyelid reconstruction.

A full description of the anatomy of these flaps is given in the first section of this chapter and suffice it to say that they have proved very reliable. The donor site, being within the hair line, is inconspicuous and the superficial temporal fascia is readily dissected and turned inferiorly to cover a cartilage framework. The fascia accepts a skin graft readily (fig. 4,15).

These flaps are of course not comprised of deep fascia, but of the thinner, suppler superficial temporal fascia. They do serve to remind one of the concept of pure fascial flaps in the limbs and although we have not used anything more



4.15 Superficial temporal fascia used for ear reconstruction.

than very small transposition flaps of fascia outside the head, both local and free deep fascial flaps have been used by others (Walton et al. 1985, Thatte et al. 1984).

Comment

In all a total of more than 80 fasciocutaneous flaps have been used by us over the last 8 years with gratifying results (Table 4.1). The complications are described in Chapter 5.

If one were to include the deltopectoral flaps and radial forearm flaps performed by colleagues in our department over this period the total would probably exceed 100 cases which demonstrates the widespread clinical use and value of the fasciocutaneous flap.

Although the fasciocutaneous flap has enabled larger defects to be closed with local tissue there is a limit to the size of flaps in various areas. In cases where even larger flaps are needed tissue expansion has solved many of these problems. It is possible to insert tissue expanders beneath the deep fascia but there are some draw backs to this technique. Since the deep fascia in the limbs tends to be dense and inextensible, it may be difficult to close the fascia over the tissue expander. On the trunk, because the fascia is thinner, closure should not present a problem.

Tissue expansion in the lower leg has not been free of complications and we have suggested that in the lower leg, in particular, the expander should be inserted beneath the fascia. This extra layer should reduce the risk of skin perforation once expansion is begun. Again total closure of the fascia may be impossible but if the fascia is partially sutured and 3 or 4 weeks allowed to elapse before expansion is begun, a satisfactory result can be achieved.

References Chapter 4

1. Abdul-Hassan, H.S., Ascher, G. and Acland, R.D. (1986) Surgical anatomy and blood supply of the fascial layers of the temporal region. Plast. Reconstr. Surg. 77, 17.
2. Avelar, J.M. and Psillakis, J.M. (1981) The use of galea flaps in craniofacial deformities. Ann. Plast. Surg. 6, 464.
3. Barclay, T.L., Cardoso, E, Sharpe, D.T. and Crockett, D.J. (1982) Repair of lower leg injuries with fasciocutaneous flaps. Brit. J. Plast. Surg. 35, 127.
4. Bohmert, H. (1980) Experience in breast reconstruction with thoraco-epigastric and advancement flaps. Acta. Chir. Belg. 79, 105.
5. Bowen J. and Meares A. (1974) Delayed local leg flaps. Brit. J. Plast. Surg. 27, 167.
6. Brent, B., Upton, J., Acland, R.D., Shaw, W.W., Finseth, F.J., Rogers, C., Pearl, R.M. and Hentz, V.R. (1985) Experience with the temporoparietal fascial free flap. Plast. Reconstr. Surg. 76, 1, 177.
7. Budo, J., Finucan, T. and Clarke, J. (1984) The inner arm fasciocutaneous flap. Plast. Reconstr. Surg. 73, 4, 629.

8. Calderon, W., Chang, N. and Mathes, S. (1986) Comparison of the effect of bacterial innoculation in musculocutaneous and fasciocutaneous flaps. Plast. Reconstr. Surg. 77, 185.
9. Casey, R.P. (1984) Le lambeau cutaneo-aponevrotique aux membres inferieurs: sa cartographie, techniques et indications. These pour le doctorat en médecine.
10. Casey, R.P. (1986) Les lambeaux fasciocutanes pédicules a la jambe. Encyclopédie Médico-Chirurgicale Paris 45850, 4.11.11., 1.
11. Chang, T. and Hwang, W. (1984) Forearm flap in onestage reconstruction of the penis. Plast. Reconstr. Surg. 74, 2, 251.
12. Cormack, G.C. and Lamberty, B.G.H. (1984) Fasciocutaneous vessels in the upper arm: application to the design of new fasciocutaneous flaps. Plast. Reconstr. Surg. 74, 2, 244.
13. Dolmans, S., Guimberteau, J.C. and Baudet J. (1979) The upper arm flap. Microsurg. 1, 162.
14. Donski, P.K. and Fogdestam, I. (1983) Distally based fasciocutaneous flap from the sural region. Scand. J. Plast. Reconstr. Surg. 17, 191.
15. Fisher, J. (1985) External oblique fasciocutaneous flap for elbow coverage. Plast. Reconstr. Surg. 75, 1, 51.
16. Fisher, J. and Wood, M.B. (1987) Experimental comparison of bone revascularisation by musculocutaneous and cutaneous flaps. Plast.Reconstr. Surg. 79, 81.
17. Grabb, W.C. and Argenta, L.C. (1981) The lateral calcaneal artery skin flap. Plast. Reconstr. Surg. 68, 2, 723.
18. Haertsch, P.A. (1981a) The surgical plane in the leg. Brit. J. Plast. Surg. 34, 464-469.
18. Haertsch, P.A. (1981b) The blood supply to the skin of the leg: a postmortem investigation. Brit. J. Plast. Surg. 34, 470-477.
19. Harii, K., Ebihara, S., Ono, I., Saito, H., Terni, S. and Takato, T. (1985) Pharyngeal reconstruction using a fabricated forearm free flap. Plast. Reconstr. Surg. 75, 2, 463.
20. Holmes, J. and Rayner, C.R.W. (1984) Lateral calcaneal artery island flaps. Brit. J. Plast. Surg. 37, 402.
21. Hyrtl, Über das verhalten der Blutgefässe in dem fibrosen Gewebe (1859) Oesterreichische Zeitschrift für praktische Heilkunde 5, 128.
22. Jackson, I.T., Adham, M.N. and Marsh W.R. (1986) Use of galeal frontalis myofascial flap in craniofacial surgery. Plast. Reconstr. Surg. 77, 2, 905.
23. Jayes, P.H. (1950) Cross-leg flaps - a review of 60 cases. Brit. J. Plast. Surg. 3, 1.
24. Kaplan E.N. and Pearl, R.M. (1980) An arterial medial arm flap: vascular anatomy and clinical applications. Ann. Plast. Surg. 4, 205.
25. Lamberty, B.G.H. (1979) The supraclavicular axial patterned flap. Brit. J. Plast. Surg. 32, 207.
26. Lamberty, B.G.H. and Cormack, G.C. (1983) The antecubital fasciocutaneous flap. Brit. J. Plast. Surg. 36, 428.
27. Lovie, M.J., Duncan, G.M. and Glasson, D.W. (1984) The ulnar artery forearm free flap. Brit. J. Plast. Surg. 37, 486.
28. McCraw, J.B., Massey, F.M., Schanklin, K.D. and Horton C.E. (1976) Vaginal reconstruction with gracilis myocutaneous flaps. Plast. Reconstr. Surg. 58, 2, 176.
29. McCraw, J.B., Fishman, J.H. and Sharzer, L.A. (1978) The versatile gastrocnemius myocutaneous flap. Plast. Reconstr. Surg. 62, 15.
30. McCraw, J.B. and Arnold, P.G. (1986) Pectoralis myocutaneous flap. McCraw and Arnold's Atlas of muscle and musculocutaneous flaps. Hampton Press Publishing Co. Norfolk, Virginia. p. 119.
31. Masquelet, A.C., Rinaldi, S., Mochet, A. and Gilbert, A. (1985) The posterior arm free flap. Plast. Reconstr. Surg. 76, 6, 908.
32. Morris, A.M. and Buchan, A.C. (1978) The place of the cross-leg flap in reconstructive surgery of the lower leg and foot: a review of 165 cases. Brit. J. Plast. Surg. 31, 138.
33. Mühlbauer, W., Herndl, E. and Stock, W. (1982) The forearm flap. Plast. Reconstr. Surg. 70, 336.
34. Nahai, F., Hill, H. and Hester, T. Experiences with the tensor fascia lata flap. (1979) Plast. Reconstr. Surg. 63, 788.

35. Robson, M.C. (1986) Discussion of comparison of musculocutaneous and fasciocutaneous flaps. Plast. Reconstr. Surg. 77, 793.
36. Russell, R.C., Guy, R.J., Zook, E.G. and Merrell, J.C. (1985) Extremity reconstruction using the free deltoid flap. Plast. Reconstr. Surg. 76, 4, 586.
37. Thatte, R.L. and Laud N. (1984) The use of the fascia of the lower leg as a roll-over flap. Brit. J. Plast. Surg. 37, 88.
38. Tolhurst, D.E., Haeseker, B. (1982) Fasciocutaneous flaps in the axillary region. Brit. J. Plast. Surg. 35, 340.
39. Tolhurst, D.E., Haeseker, B. and Zeeman, R.J. (1982) Fasciocutaneous flaps. Chir. Plastica 7, 11.
40. Tolhurst, D.E., Haeseker, B. and Zeeman, R.J. (1983) The development of the fasciocutaneous flap and its clinical applications. Plast. Reconstr. Surg. 71, 5, 597-605.
41. Tolhurst, D.E. and Huygen, R.E.F. (1986) Tie-over sutures fixed by staples. Brit. J. Plast. Surg. 39, 565.
42. Vasconez, L. (1986) Abdominal flaps. First Asean flap dissection workshop. Singapore.
43. Walton, R.L., Matory, W.E. and Petry J.J. (1985) The posterior calf fascial free flap. Plast. Reconstr. surg. 76, 6, 914.
44. Yang, G., Chen, B., Gao, Y., Liu, X., Li, J., Tiang, S. and He, S. (1981) Forearm free skin flap transplantation. Nat. Med. J. China 61, 139.

Chapter 5

INDICATIONS AND COMPLICATIONS

As is so often the case when a new and promising technique is introduced, enthusiasm can lead one to expect too much of the novelty. This was the case with the fasciocutaneous flap and was due in part to an imperfect understanding of the blood supply of the skin. Although we were fairly quick to realise that the fasciocutaneous system was only one part of the tripartite system supplying the skin, it was only with increasing experience that we came to understand that each of the three systems tends to have a dominant rôle in certain areas of the body. This view has been supported and enlarged upon by Nakajima et al. (1986).

Anatomical investigations also demonstrated this point and clarified the areas in which different types of fasciocutaneous flaps could be expected to survive. Hand in hand with this evolution of our understanding, went the development of the new flaps suitable for use as free flaps, described in Chapter 4. By and large these flaps were the product of careful anatomical studies which guaranteed their reliability, provided of course that there were no technical problems during vessel anastomosis.

It was decided to deal with indications and complications in one chapter since there is often a close relationship between the two; complications frequently develop following a human error, as when for example there is no good indication for a specific procedure. It is obvious that the indications for a surgical operation cannot be simply learned from a book. Each patient's specific problem, their general health and the condition of the tissues at the site of the proposed operation must all be carefully considered before a decision is made. This latter itself, is sometimes tempered by experience or advice. Last but not least the plan should be explained to the patient, with whom the ultimate decision rests.

Thus it is that due to oversight or misunderstanding or poor judgement, problems, dissatisfaction or complications develop. Ignorance, stupidity and carelessness are best not highlighted but should also not be forgotten.

Indications for fasciocutaneous flaps

It has been instructive to reread my thoughts of only two and a half years ago, as even in this relatively short period my views have changed, (Tolhurst 1984).

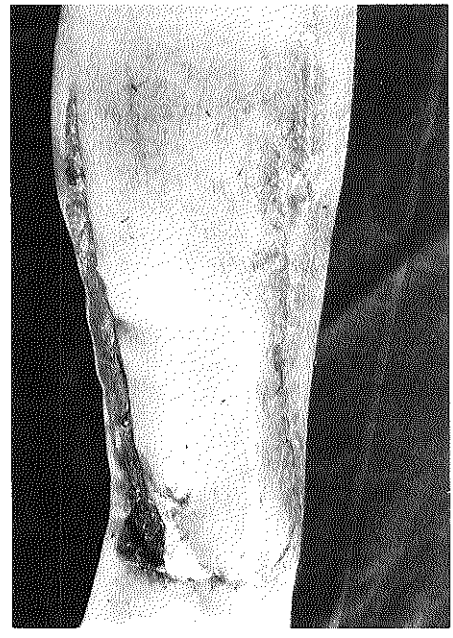
In certain areas of the body it seems that the fasciocutaneous vascular system is dominant and a fasciocutaneous flap would naturally be the flap of choice.

It has also become clear that it is preferable to raise a fasciocutaneous flap so that its long axis parallels an axial blood supply if this is present. In the lower leg, for example fasciocutaneous flaps are as a rule best raised with a proximally sited base so that the flap is orientated supero-inferiorly.

In 1984 I stated that fasciocutaneous flaps were worthy of consideration for the repair of poorly vascularised tissue in the lower leg. This is still the case but muscle flaps, if available would be my first choice. Again the site and type of lesion may be such that a fasciocutaneous flap is preferable. In general fresh, shallow skin defects exposing intact bone are most suitable for fasciocutaneous flaps.

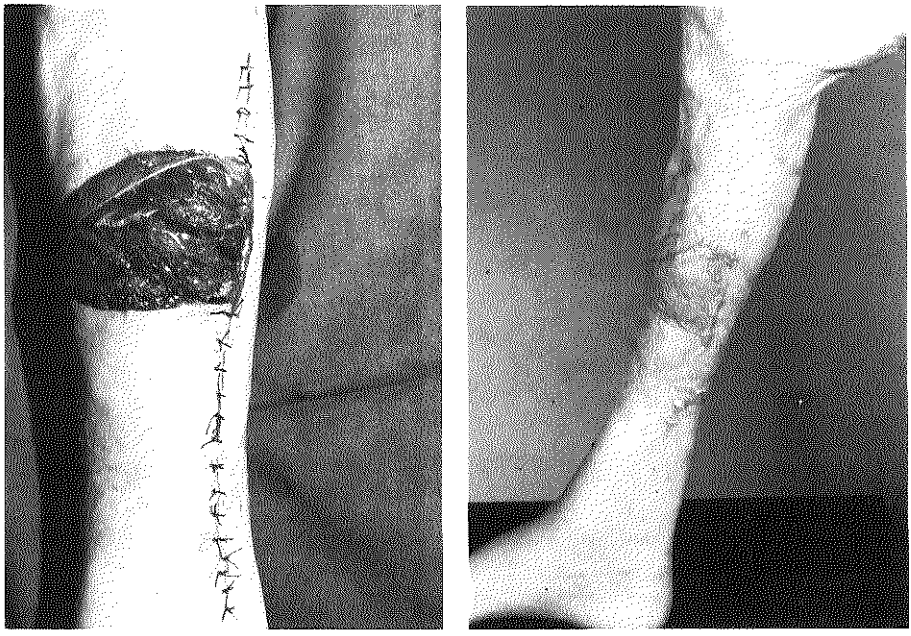
Where the skin and subcutaneous tissue is densely scarred or pigmented with deposits of haemosiderin, it has proved unwise to raise fasciocutaneous flaps. Such areas are commonly found in the lower leg and are associated with repeated, unsuccessful attempts to close a wound or with venous insufficiency.

In the lower leg, cosmesis is an important consideration in female patients and as a rule the donor site of a fasciocutaneous flap requires a skin graft. A majority of lower leg flaps are raised on the medial side of the leg which means the skin graft will be situated postero-medially and this is a relatively favourable position. Despite the fact that the graft is placed on muscle, we have had some graft failures complicated by slow healing. The initial appearance of the donor site has thus been ugly (Fig. 5,1).



5.1 Incomplete take of skin graft at donor site. Ugly scar can result.

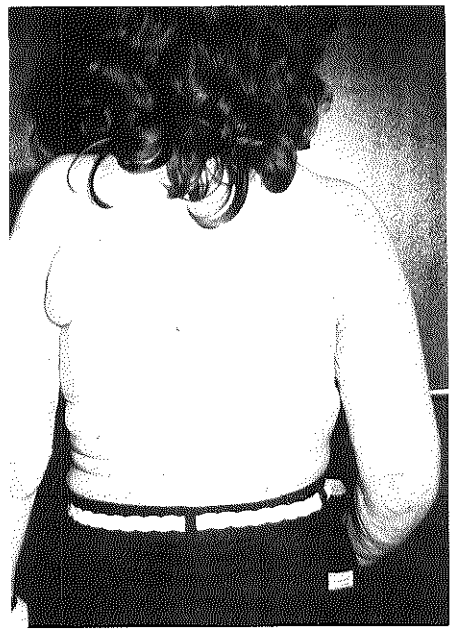
A small muscle flap transposed to cover bone, although initially bulky will slim down by as much as 50% and if successfully grafted can produce a very good cosmetic result (Fig. 5,2). The size of many fasciocutaneous flaps on the lower leg are close to 20 by 7 cms. and it can be argued that the associated scars are longer and thus less acceptable than those resulting from a muscle flap. The simplicity of the fasciocutaneous flap is on the other hand strongly in its favour.



5.2 Soleus transposition and skin graft. Good result.

Axillary and neck contractures are particuraly prone to recur following correction with split skin grafts and flaps can afford a simple, one stage correction.

Many axillary contractures are associated with chest scars or grafts which means that the addition of more scars or grafts to the area is not at all objectionable. It is frequently possible to close the donor site of a posterior thoracic flap and the scar usually settles well. For major axillary contractures this is my treatment of choice. Smaller anterior axillary contractures can be corrected by inner arm fasciocutaneous flaps but care should be taken not to divide the medial cutaneous nerve of the arm and forearm. Budo et al. (1984) have reported this complication as well as a dog ear at the base of the flap when the arm is abducted. A dog ear posteriorly (Fig. 5, 3) is often seen after a large posterior thoracic flap has been used but patients have not complained about this.



5.3 Axillary dog-ear following use of posterior thoracic flap.

If a decision to use a flap for neck correction is made, the choice lies between a free radial forearm flap, an epaulette or an anterior thoracic flap. The latter is best reserved for cases were there is chest scarring. Mitz (1986) and Staub et al. (1986) have used this flap with success as have we. Both the anterior and posterior thoracic flaps have included skin grafted areas after these have settled and softened and no loss of tissue was observed.

One of the advantages of the fasciocutaneous flap over the musculocutaneous flap is that it is thinner. Thus for defects where fat and skin alone are missing, fasciocutaneous flaps are often preferable. The anterior neck is one example; the hand, vulva and introitus are others. Local flaps have proved satisfactory in the perineal and vulval areas where scarring is less of a problem. The epaulette flap donor site is apt to leave ugly scars when grafted and patients should be selected with care.

Increasing experience is revealing new flaps and confirming the value of the fasciocutaneous principle. One example is the successful series of 31 upper forearm fasciocutaneous flaps used by Bunkis et al. (1985) for periolecranon defects. With one exception, the fasciocutaneous flap has proved of most use in the lower leg. The exception is the free fasciocutaneous flap and in particular the radial forearm flap. The widespread uses of this flap both as a local and free flap have already been mentioned. With increasing experience, the free

radial forearm flap has proved to be most reliable and again can be one's first choice where a large, thin free flap is needed. Of the many other free fasciocutaneous flaps available, the scapular and the lateral upper arm flap are also popular where smaller areas of skin are required.

Free flaps have changed the whole complexion of plastic surgery but as Mitz (1986) says in his article on the fasciocutaneous flap as an alternative solution, these new flaps "may be safely used when previously we would have considered free flaps as the best choice". One must not forget that not every plastic surgeon is trained in microsurgery and not all departments have a microscope. Microsurgery could not now exactly be called a luxury but it is a costly undertaking.

Complications

In a comment on an earlier article on fasciocutaneous flaps, Nahai (1984) expressed his regret that I made only a brief reference to complications. This situation was to some extent redressed in the following article (Tolhurst, 1986) but as Nahai said, these flaps will assume their correct place in our repertoire once more is learnt from the limitations and complications attendant upon their use.

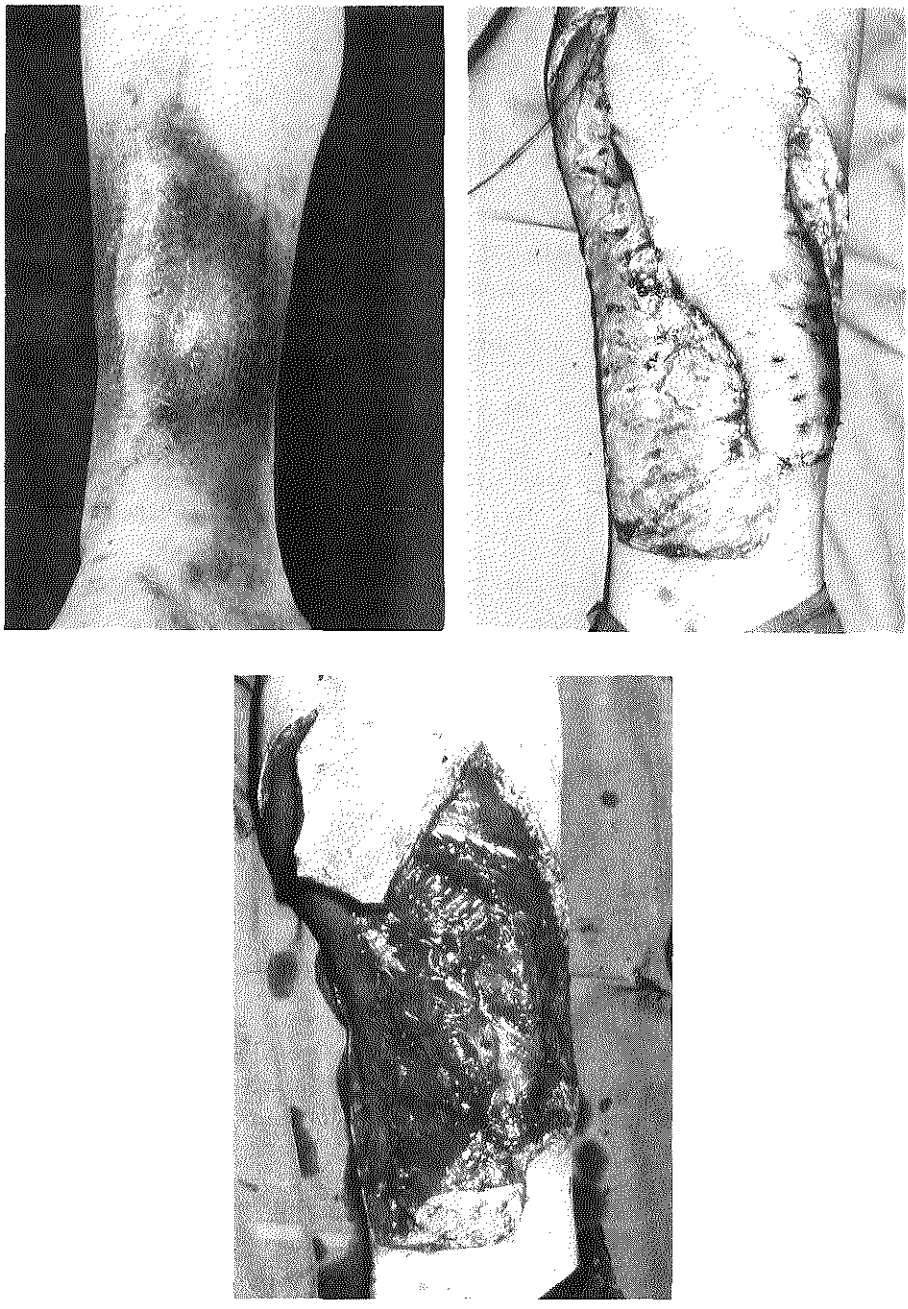
In a way I am glad I had little to say on the subject of complications as they are something that every plastic surgeon hopes to avoid.

Just over 80 fasciocutaneous flaps have been used in our department and in table 5,1 their distribution and the major complication rate is shown. The principal concern has been with the success and survival of fasciocutaneous flaps. Major complications are those in which a substantial part of the flap has been lost, resulting in failure of the surgical goal.

THE LEG

For example if in an attempt to cover exposed bone in the lower leg, a portion of the flap has necrosed and the bone has been re-exposed, the procedure would be deemed a failure and a major complication. This has occurred twice in the lower leg and in retrospect was due to poor clinical judgement on my part. As mentioned earlier, pigmented, scarred and indurated skin is not a suitable donor area, (Fig. 5, 4).

In some cases even though the skin has necrosed the deep fascia has survived and been grafted but we have not encountered this situation. A less major complication has been marginal loss of skin only or of the full thickness of the flap necessitating only skin grafting. Again a relatively minor complication has been incomplete take of the split skin graft at the donor site (Fig. 5, 1). This can be an annoying problem if healing is retarded but in 2 cases in which



5.4 Pigmented, indurated lower leg skin. Flap necrosis; defect closed with soleus transposition.

this occurred the flap itself remained fully viable. In both cases there were grounds for suspicion of automutilation!

Distally based fasciocutaneous flaps in the lower leg have been known to necrose over half their length and one should probably limit them in size so as not to exceed the 2 to 1 length-breadth ratio.

In the thigh about half of a fasciocutaneous flap raised in a scarred area near the site of a haemolymphangioma was lost. Although the skin and fascia appeared healthy during the operation, the flap was raised oblique to the long axis of the thigh and the axiality of the fasciocutaneous system in the area was thus not fully respected. This error was made before the concept of axiality in the fasciocutaneous system was properly appreciated.

THE TRUNK

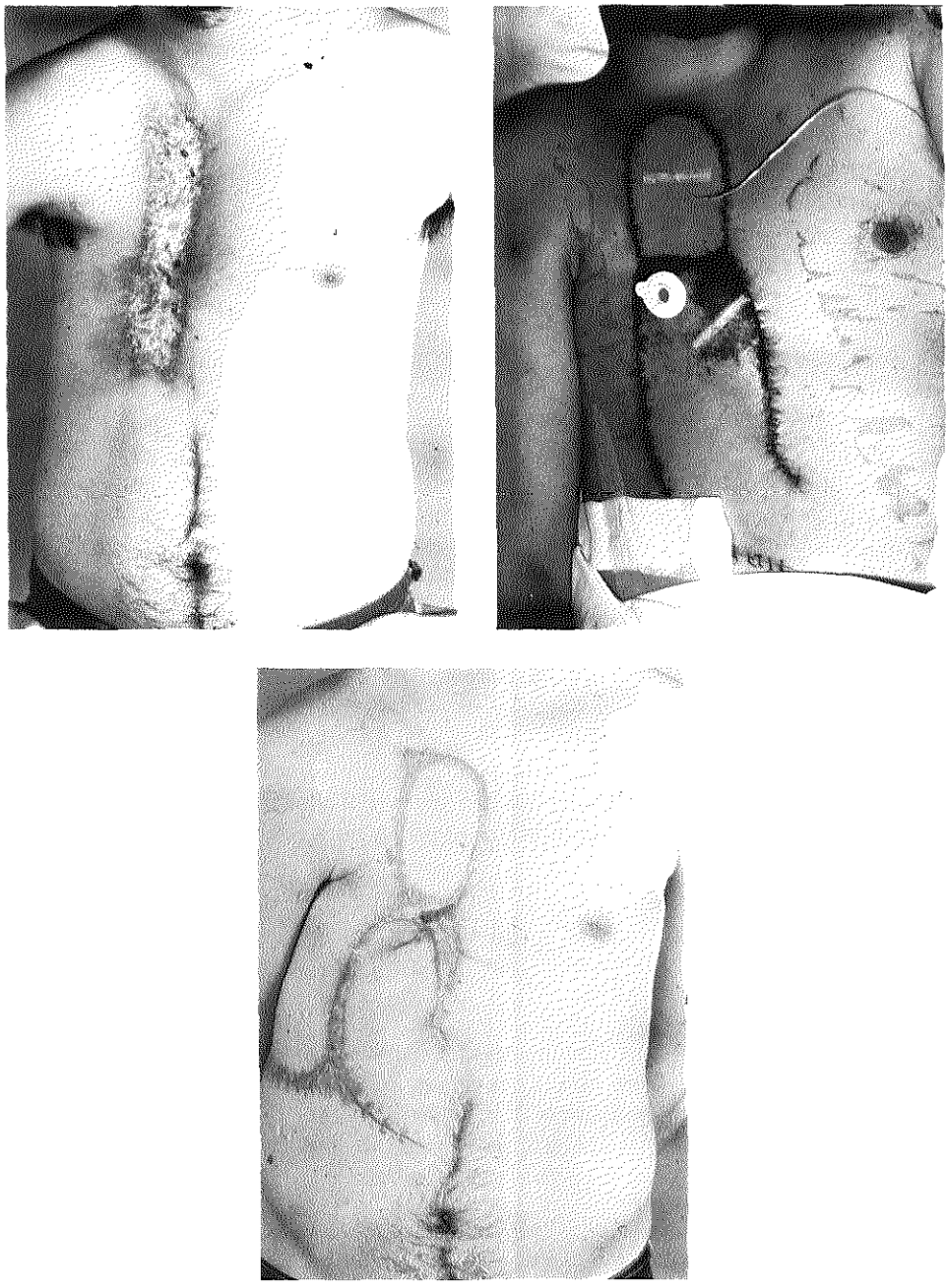
The major complication described is shown in Fig. 5,5. This flap encroached upon a vascular system which was later described and if its length had been reduced by the amount which overlapped that system, no necrosis would have occurred. This was a problem occasioned by inadequate anatomical knowledge and unfounded confidence in a new technique.

In our series of flaps used for the correction of axillary contractures only one significant area of flap loss occurred in an overweight patient. The distal quarter of the flap sloughed but healing was spontaneous and the functional result was unimpaired.

I have heard of one case in which a vertically orientated fasciocutaneous flap was raised just lateral to the lumbar spine. This became necrotic and little wonder since the vascular pattern in this region is horizontally and not vertically disposed.

THE ARM

Our experience with fasciocutaneous flaps is very limited. Part of an extended middle colateral artery flap used to cover an area of exposed radius in a drug addict was lost but in mitigation it must be said that the patient was found smoking in the recovery room, still half asleep. In this case the distal third of the flap necrosed but some deep fascia survived and was later skin grafted.



5.5 Loss of distal half of fasciocutaneous flap. Flap should have been shorter and the upper latissimus musculocutaneous flap larger.

General comments

Problems with donor site scars in the supraclavicular region have already been mentioned. Elsewhere the skin grafted donor site has been a target for criticism, particularly on the arm. However fasciocutaneous flaps have invariabley been used to solve chronic or functional disturbances and in such cases the price of an area of skin graft does not seem to be too high a one to pay for a reliable, simple one stage corrective procedure.

From table 5,1 it can be seen that out of 81 fasciocutaneous flaps a total of 12 complications developed, 6 of which involved major loss of tissue. Most

Table 5,1. Fasciocutaneous flap complications.

	Number of flaps used	Complications	Type of complication
Lower leg	25	2 major	Loss of distal 1 /2 flap - bone re-exposed
		4 minor	2 marginal loss of flap
			2 poor take of skin graft at donor site
Thigh	22	2 major	Loss of distal 3 /4 flap - axiality not respected
			Loss of distal 1 /2 flap - old scar in flap
Thorax	28	1 major	Loss of distal 1 /3 flap - flap too long
		2 minor	Tips of flaps lost - spontaneous healing
Abdomen	1		
Arm	5	1 major	Loss of distal 1 /3 flap
Total	81	12	

of these were earlier on in our series and more recently we have had less in the way of problems. Pontén had 3 failures from his initial 23 flaps and Barclay 2 small areas of skin loss in 16 lower leg flaps. The only other large series of flaps reported (Bunkis et al. 1985) was 30 cases of periolecranon defects. A proximally based forearm flap was used and only 3 relatively minor complications developed.

Advantages of fasciocutaneous flaps

Many years ago I worked for an elderly surgeon who, for reasons best known to himself, seemed principally concerned with the prevention of progress in plastic surgery. It was most instructive to see an exposed lung covered with a split skin graft and equally disappointing to be told that cranio-facial surgery was a dangerous flash in the pan that had no place in the future of our specialty.

One wonders what he would have made of all the new developments in the last 10 years but perhaps because of its simplicity, the fasciocutaneous flap may have received a grudging stamp of approval. Einstein himself, realised the importance of simplicity. I append here a list of advantages attributable to the

fasciocutaneous flap, amongst which the simplicity of the concept is perhaps the most appealing.

Singly and together these qualities will to some extent influence the surgeon in his choice of a reparative procedure and thus are they inextricabley related to the indications for and the complications of the chosen treatment.

1. Simple concept
2. Easy dissection
3. Minimal bleeding
4. Anatomical plane respected
5. Axial vessels protected
6. Perforating and conducting vessels readily seen
7. Less bulky than musculo-cutaneous flaps
8. No functional disturbance
9. Donor site readily grafted
10. Length-breadth ratio more flexible
11. Reliable results
12. Good fasciocutaneous free flaps available

References Chapter 5

1. Bunkis, J., Ryn, R.K., Walton, R., Epstein, L.I. and Vasconez, L.O. (1985) Fasciocutaneous flap coverage for periolecranon defects. Ann. Plast. Surg. 14, 4, 361.
2. Mitz, V. (1986) The fasciocutaneous flap as an alternative solution in difficult reconstructive problems. Ann. Plast. Surg. 17, 3, 206.
3. Nahai, F. (1984) Invited comment on surgical indications for fasciocutaneous flaps. Ann. Plast. Surg. 13, 6, 502.
4. Nakajima H., Fujino T. and Adachi S. (1986) A new concept of vascular supply to the skin and classification of skin flaps according to their vascularisation. Ann. Plast. Surg. 16, 1, 1.
5. Staub S., and Pugash E. (1986) Treatment of cervical burn contracture with two fasciocutaneous flaps. Case report. Ann. Plast. Surg. 17, 4, 350.
6. Tolhurst, D.E. (1984) Surgical indications for fasciocutaneous flaps. Ann. Plast. Surg. 13, 6, 495.
7. Tolhurst, D.E. (1986) Clinical experience and complications with fasciocutaneous flaps. Scand. J. Plast. Reconstr. Surg. 20, 75-78.

SUMMMARY

It was originally my intention to base my thesis on 5 papers published in each of the main international plastic surgery journals but it seemed wiser to incorporate my experience with fasciocutaneous flaps in the present format to obviate repetition.

Chapter 1 traces the development of flap surgery from the first attempts of surgeons to introduce the element of science to the art of flap design. The tube pedicle, muscle flap, random and axial flaps and the musculocutaneous flap, all flit across the stage before the fasciocutaneous flap makes its entry.

Two long forgotten works in the German and French languages are mentioned to illustrate that much of what we now regard as new is in fact quite old. These works underline the importance of the anatomical details of the blood supply to the skin which is the basis of success in flap surgery.

The object of the study was to confirm that fasciocutaneous flaps are safe, simple and reliable in the leg. By applying the principles of the technique elsewhere in the body it was possible to develop a variety of fasciocutaneous flaps which have proved useful in reconstructive surgery.

Chapter 2 is concerned with the classification of flaps in general as well as the subclassification of fasciocutaneous flaps. My "atomic system" of flap classification is new and embraces all the possible tissue components and secondary characteristics of flaps under two main headings. Classification is not only of use as a teaching device but it fosters orderly thoughts and sound decisions.

In Chapter 3 the concept of a tripartite blood supply to the skin is introduced. The components are not new but their integration as the main basis for variable skin perfusion and flexible flap design is perhaps not yet widely accepted or understood. The main body of the chapter is concerned with the blood vessels related to the deep fascia. A short historical survey of the work concerned with this subject is followed by a detailed description of the fasciocutaneous system. The chapter concludes with a section devoted to the regional orientation of fasciocutaneous vessels in various areas of the body.

For those practising plastic surgery Chapter 4 may prove of some interest and I hope some use. It begins by outlining the experience acquired in our department with an assortment of fasciocutaneous flaps and the reader will I trust divine the debt I owe to many of our assistants in the accounts of some of our minor surgical adventures. I do not claim to have had a hand in all

the 80 odd cases of fasciocutaneous flaps used but I was involved in the majority of cases if only to take or share the blame when things did not work out according to plan. The gratification engendered by success has on the other hand been something that can also be shared.

Fasciocutaneous flaps in common use or deemed to have clinical potential are described in the second main section of Chapter 4. The flaps are listed under 4 regional headings (head and neck, arm, trunk, lower limb) and in each region specific and random flaps are described.

Finally the important subjects of indications for and complications with fasciocutaneous flaps are dealt with in Chapter 5. There has been scarcely any work published on both these subjects. The reader must on this account forgive the truisms encountered. Perhaps he will accept my admissions and descriptions of complications as a penance for inflicting such irritation on his worthy person.

SAMENVATTING

Oorspronkelijk was ik van plan, 5 artikels die in de belangrijkste internationale tijdschriften voor plastische chirurgie zijn verschenen samen te bundelen als proefschrift, maar om herhaling te voorkomen dacht ik dat de huidige versie beter zou zijn.

Hoofdstuk 1 gaat over de ontwikkeling van de chirurgische toepassingen van gesteelde lappen vanaf de eerste pogingen om de wetenschap aan de kunst van lap-ontwerp voor te stellen. De buislap, spierlap, random en axiale lappen en de musculocutane lap verschijnen op het toneel voordat de fasciocutane lap zijn entree maakt.

Twee werken in het Duits en Frans, al lang vergeten, laten zien dat wat wij nieuw vinden eigenlijk vaak tamelijk oud is. Deze boeken demonstreren de belangrijkheid van de details van bloedvoorziening van de huid, die de basis voor het succes bij lap chirurgie vormt.

Het doel van de studie was om te bevestigen dat fasciocutane lappen in het been veilig, simpel en betrouwbaar zijn. Toen de principes van de techniek elders in het lichaam toegepast werden, was het mogelijk om een assortiment fasciocutane lappen te ontwikkelen, die in de reconstructieve chirurgie van nut zijn.

Hoofdstuk 2 heeft te maken met de classificatie van lappen in het algemeen en tevens de classificatie van fasciocutane lappen. Mijn atomisch systeem van lap classificatie is iets nieuws en behelst in 2 onderdelen alle mogelijke weefselcomponenten en de secondaire eigenschappen. Deze classificatie is niet alleen van belang voor onderwijs-doeleinden maar bevordert ook de besluitvorming bij klinische problemen.

In Hoofdstuk 3 wordt het idee van een driedelige (tripartite) bloedvoorziening van de huid geïntroduceerd. De componenten zijn niet nieuw maar hun integratie als de basis voor de variabele perfusie van de huid en voor het flexibele lapontwerp is nog niet in het algemeen geaccepteerd of begrepen.
Het belangrijkste deel van dit hoofdstuk gaat over die bloedvaten welke een verhouding met de diepe fascia hebben. Een kort historisch overzicht van dit onderwerp wordt door een gedetailleerde scriptie van het fasciocutaan systeem gevolgd. Dit hoofdstuk eindigt met een stuk over de regionale orientatie van fasciocutane vaten in bepaalde gebieden van het lichaam.

Voor plastische chirurgen kan Hoofdstuk 4 van belang blijken te zijn en naar ik hoop, van nut. Het begint met een samenvatting van ervaringen met fasciocutane

lappen op onze afdeling en de lezer zal waarschijnlijk tussen de regels door iets kunnen lezen over mijn dankbaarheid aan de chirurgische assistenten die meegedaan hebben met onze kleine chirurgische avonturen.

Niet al de beschreven patiënten zijn door mij geopereerd, maar ik ben er in de meeste gevallen bij betrokken geweest en heb zelfs de verantwoordelijkheid genomen voor die patiënten die niet volgens plan verliepen, maar het was ook plezierig om mee te genieten van de succesvolle ingrepen.

Fasciocutane lappen die dagelijks gebruikt worden of die veel klinisch potentieel hebben, zijn in het tweede deel van hoofdstuk 4 beschreven. De lappen zijn onder 4 regionale opschriften beschreven (hoofd-hals, arm, romp en been) en bij elke regio vindt men een samenvatting van speciale en ook random fasciocutane lappen.

Tenslotte zijn de belangrijke onderwerpen, indicaties en complicaties met fasciocutane lappen in hoofstuk 5 te vinden. Er zijn bijna geen publicaties over deze onderwerpen. De lezer moet mij verontschuldigen als hij wat "truisms" tegenkomt. Wellicht wil hij het opbiechten van de complicaties als een boetedoening voor deze irritaties zien. Het boek eindigt met een lijst van de voordelen van fasciocutane lappen.

CURRICULUM VITAE

David Erskine Tolhurst
Date of birth : 24 september 1934
Place of birth: Wellington, New Zealand.

Education:

Schools: Huntley School
Marton, New Zealand

Wanganui Collegiate School
Wanganui, New Zealand

Medical School: Otago University Medical School
Dunedin, New Zealand

Qualifications:

M.B., Ch.B. University of New Zealand 1958F.R.C.S. Royal College of Surgeons of England 1966

After spending 1959 as a house surgeon and physician in the Wellington Hospital, New Zealand, the author worked in Canada and U.S.A. until 1964. Besides travelling in both countries and doing 2 tours as a ships surgeon, he spent 12 months as a paediatric and anaesthesia resident at the University Hospital in Saskatoon and then completed a two year residency in anaesthesia in the Royal Victoria Hospital, Montreal and the Massachusetts General Hospital, Boston.

He then began his postgraduate surgical training in England and worked as a senior house officer and registrar in general surgery at St. Thomas' Hospital, Hackney Hospital and the Royal Marsden Hospital in London.

From 1967 until 1972 he trained as a registrar and senior registrar in Plastic Surgery at the London Hospital, The Queen Victoria Hospital, East Grinstead, St. Lawrence Hospital, Chepstow, the Hospital for Sick Children, Great Ormond St. and University College Hospital, London.

Following 9 months as a research fellow at the London Hospital he was appointed as plastic surgeon to the Academisch Ziekenhuis Dijkzigt, Sophia Kinderziekenhuis and the Faculty of Medicine in Rotterdam, Holland in 1973. In 1987 he accepted the chair of Plastic Surgery in the University of Leiden, Holland.

ACKNOWLEDGEMENTS

In the first place I should like to thank all the assistants with whom I have worked and in particular Barend Haeseker and Rein Zeeman. Their enthusiasm, support and help with the untried technique of fasciocutaneous flaps in the early 1980's was a great encouragement. I have drawn on their labours in the section describing our clinical experience with these flaps.

Secondly, not I hasten to add because in any way they do not deserve to be first, I am most grateful to the members of the audiovisual department of the Erasmus University Medical Faculty who have been of inestimable help over the years. Again two people to wit, Lex Doff and "Las" László deserve not only my praise for their unsurpassed professional expertise but my thanks for their unstinted and cheerful help with this and my other projects.

Finally without the patient work of three stalwart girls, Marjanne, Anco and Judith, my minor opus would never have graced the libraries of this world.

I am grateful for the generous financial support provided by the following:

AO WEST
COX UPHOFF
DAVIS + GEK SURGICAL PRODUCTS
EMDAMED
GENETIC LABORATORIES
H.S.H.
LAMERIS
LEDERLE
LILLY
MEDICAL SERVICES
3 M
NEDERLANDSE BRANDWONDEN STICHTING
ORTOMED
STÖPLER
STRŸKER
ZEISS NEDERLAND b.v.
ZIMMER