Ralph T. Manktelow

Microvascular Reconstruction

Anatomy, Applications and Surgical Technique

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With Section on Paediatrics
by Ronald M. Zuker

Foreword by G. Ian Taylor

Illustrated by Ken Finch

With 288 Figures

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Foreword

Reconstructive microvascular surgery is now in its teens. At first many thought this new child was a whim and would fail to thrive. Some were uncertain, others with vision either supported or became actively involved in this new area of surgical endeavour. Although initial interest was focused on the replantation of amputated parts, it has been the one stage free transfer of living tissue to a distant site which has launched microsurgery into the surgical spotlight.

From its humble beginnings we have witnessed a revolution in this branch of plastic surgery; many of the long established methods of reconstruction have, like barricades, fallen before the advances made in this field. In its infancy there were relatively few procedures available. There was a tendency to make the patient's problem fit the operation, rather than the reverse, and this frequently led to an inferior result. The then known flaps, such as the groin flap and the deltopectoral flap, were employed. Unfortunately they were sites which posed many technical problems; namely those of vascular anomaly, a short pedicle and vessels of small calibre. Long operations were the norm, and vascular thrombosis was not uncommon. Hospital routine often was disrupted and there was a danger that these new techniques would fall into disrepute.

Over the last decade this state of affairs has changed dramatically. There has been an explosion in the number of free flaps available to the microsurgeon, which offer both versatility and reliability. Many of these have been developed as a result of intensive investigations in the post mortem disecting room. Numerous fresh cadaver dissection and injection studies have defined the vascular architecture of various tissues and combinations of tissues. In our department at The Royal Melbourne Hospital for example over 2,000 such studies have been performed. What is most important is that many of these techniques have evolved to match the patient's needs.

With the introduction of a new flap, there is an initial wave of enthusiasm which must receed through the channels of peer appraisal, ultimately to assume as Ian McGregor has succinctly stated, "its correct pecking order". Many flaps have their champions, so it is appropriate that a book such as this be written by an ardent consumer who has no axe to grind. Ralph Manktelow is such a person and I am honoured by his request to write the foreward to this important work.

Dr. Manktelow has been more than an umpire. He is one of the second generation of surgeons who has helped refine the works of the pioneers. His enquiring mind and considerable clinical experience has offered much to the literature on this subject. In particular his refinements of the free gracilis muscle as a functional unit for reconstruction of the crippled upper limb and the paralysed face are unsurpassed.

Choosing the most appropriate flap to solve a specific reconstructive problem requires the careful analysis of many factors. What tissues do we need, from where can they be best spared, and how can we minimise patient discomfort and cost to the community? The final choice should be based on sensible planning and experience. One after all does not expect a professional golfer to ask his caddy to pass him from the bag, a putter to drive down the fairway, nor a driver to use on the green. We now have at our disposal flaps that can get us out of the rough far more readily than in bygone days. Even the "hole in one" is easier with the development of such procedures as the vascularised osteomyocutaneous flap.

This book does not pretend to cover every aspect of free flap surgery, nor does it assume to be a definitive work on the subject - for reconstructive microvascular surgery is still a rapidly expanding art. The book does however define the problem areas where, at this stage, free flap surgery has the most to offer. From the long list of described flaps Ralph Manktelow and his co-workers have selected a nucleus of reliable and versatile procedures to solve the majority of these reconstructive problems.

The description of the planning and execution of these operations is practical and informative. The illustrations are of a high standard and are designed to aid the surgeon. The book is undoubtably a valuable contribution to the literature on reconstructive surgery.

February, 1986 G. Ian Taylor

Preface

This book is designed to be a 'how to do it' text of microvascular reconstructive surgery. It discusses the selection, anatomy and surgical technique of a spectrum of free tissue transfers. It is written primarily by one surgeon, and is purposely dogmatic in the hope that it will provide useful solutions to patients' problems.

The book is divided into two sections. The first section covers the surgical anatomy and technique involved in elevating each of the free tissue transfers. The second section discusses the applications of these transfers to reconstruction in three specific areas. These areas are the three anatomical regions in which reconstructive microsurgery has made its major contributions: the head and neck, the upper extremity and the lower extremity. The only digression from this plan has been with toe and jejunum transfers. As they are used exclusively in hand, and head and neck respectively, these transfers are described in the second section. Since most of the free tissue transfers are used in all three anatomic regions, rather than repeat their description in each region of application, I have described each transfer once and grouped these descriptions at the front of the book to form Section One.

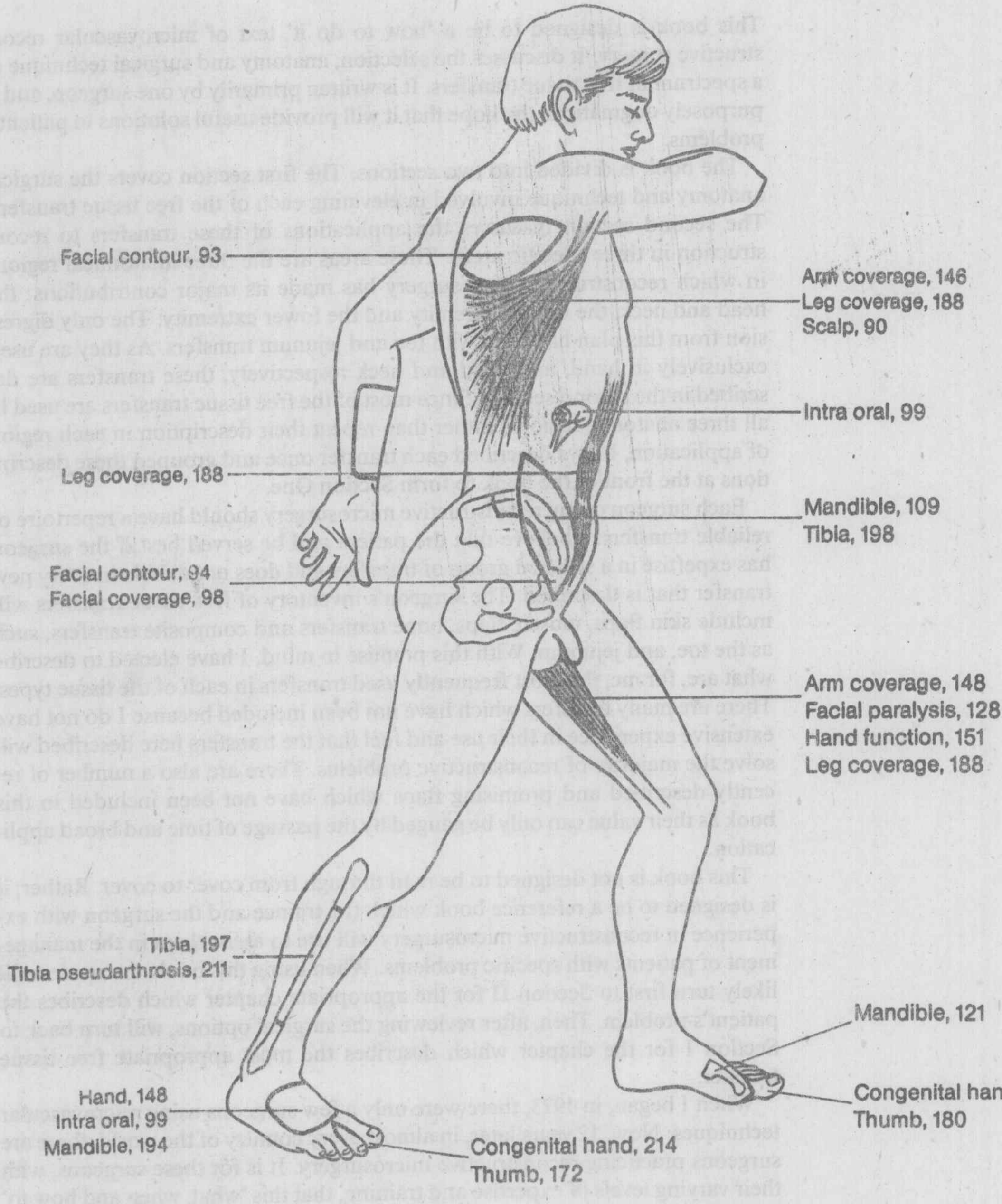
Each surgeon doing reconstructive microsurgery should have a repertoire of reliable transfers. I believe that the patient will be served best if the surgeon has expertise in a selected group of transfers and does not dabble in every new transfer that is described. The surgeon's inventory of free tissue transfers will include skin flaps, muscle flaps, bone transfers and composite transfers, such as the toe, and jejunum. With this premise in mind, I have elected to describe what are, for me, the most frequently used transfers in each of the tissue types. There are many transfers which have not been included because I do not have extensive experience in their use and feel that the transfers here described will solve the majority of reconstructive problems. There are also a number of recently described and promising flaps which have not been included in this book as their value can only be gauged by the passage of time and broad application.

This book is not designed to be read through from cover to cover. Rather, it is designed to be a reference book which the trainee and the surgeon with experience in reconstructive microsurgery will use to assist them in the management of patients with specific problems. When using this book, the reader will likely turn first to Section II for the appropriate chapter which describes the patient's problem. Then, after reviewing the surgical options, will turn back to Section I for the chapter which describes the most appropriate free tissue transfer.

When I began, in 1973, there were only a few surgeons using microvascular techniques. Now, 12 years later, in almost every country of the world, there are surgeons practicing reconstructive microsurgery. It is for these surgeons, with their varying levels of expertise and training, that this 'what, when and how to' book is written.

Toronto, February 1986 — Ralph T. Manktelow

Topographical Index by Region of Application



Acknowledgements

The development of my microsurgical practice was stimulated by exposure to Harry Buncke, John Cobbett, Bob Acland, Bernie O'Brien, Ian Taylor, Chen Zhong-wei, Kiyonori Harii, Alain Gilbert and Harold Kleinert. These surgeons are some of the early giants in reconstructive microsurgery and to them I am most grateful for their teaching and encouragement.

In Toronto, I have had the special pleasure of taking part in the training of other surgeons, and having some of them join me as colleagues. In this manner, Drs. Nancy McKee, Ron Zuker, Jim Mahoney and Brian Boyd and I have developed a group who operate together, form a post graduate teaching service and share in research investigations. The experience of this group has been broadly based with a major microsurgical activity in all three areas of reconstructive microsurgery - the head and neck, the upper extremity and the lower extremity. Included in this book are many of the principles and prejudices developed by these surgeons. I appreciate their contribution.

I am particularly fortunate to have worked with Dr. Ron Zuker as a friend and co-surgeon on most of our difficult cases. Not only does he provide the hands of a skilled microsurgeon, but for these cases, brings an almost intuitive sense of what will work best. From this close co-operation, there have been many benefits to the patient, to the development of the field of reconstructive microsurgery, and to our trainees. As Dr. Zuker has a special interest in children's surgery, he has written the chapter on Paediatric Microsurgery.

Our experience in microsurgery involves over 300 replantations and over 300 free tissue transfers. With these cases, our Fellows and Residents have provided an intellectual stimulus and an untiring support for the heavy demands of the service, and to them I give my sincere thanks.

This book was written with the assistance of my wife, Marg, who provided an incisive editorial pen. For this help and her patience during the preparation of the manuscript, I am most appreciative.

I am particularly grateful for the perseverence of my secretary, Elizabeth Atkinson, who has shepherded this book through its multiple revisions and reorganizations. She accepted the manuscript's preparation with the same good humor, skill and enthusiasm which she puts into the management of my surgical practice.

The realization of this book was possible to a large extent because of the efforts of Ken Finch. His illustrations illuminate the techniques and concepts which are the message of this book. The clarity of his illustrations reflect his understanding of the operative procedures and desire for logical communication.

Table of Contents

Chapter 1. Preamble

There are many good texts and manuals which describe the techniques of microvascular anastomoses. It is not the intention of this book to duplicate these descriptions, as it is assumed that the surgeon who uses this book will be skilled in these techniques. The microvascular trainee will quickly appreciate that the microvascular anastomosis, although critical to flap survival, is often the easiest part of a free tissue transfer. More difficult and requiring a broad training and experience in reconstructive surgery is the decision making which goes into each procedure. The success of each reconstruction is as much related to the thoroughness of the preoperative planning as it is to the execution of the operative procedure.

The surgeon wishing to do reconstructive microsurgery will require post graduate training in a centre which specializes in a large volume of reconstructive microsurgery. Before coming to the operating room, the surgeon will have worked in the laboratory and mastered end to end arterial and venous anastomoses, end to side repairs, and the repair of grafts between dissimilar sized vessels. When these skills are developed, he or she is then ready for training in the application of these anastomotic skills to reconstructive techniques.

Free tissue transfers for coverage, although still a valuable application of microsurgical techniques, lead the way to more complex and technically demanding procedures. These are the osteocutaneous reconstructions of the extremities and mandible, toe and partial toe transfers and the functioning muscle reconstructions of the face and extremities. The need to conceptualize, in three dimensions, a reconstruction which includes different but attached tissues, such as skin, muscle and bone, has placed increasing demands upon the reconstructive surgeon.

The development of new free tissue transfers has required an improved understanding of vascular anatomy. Considerable effort has been spent investigating the vascular territories which are supplied by various arteries, and determining the amount of tissue which the artery will support. In developing new transfers, surgeons have had to understand anatomical details which have never previously had an application to reconstructive surgery.

Preoperative Planning

Preoperative planning begins with an assessment of the patient's functional and anatomic deficit. The complete armamentarium of reconstructive techniques should then be reviewed and the technique which provides the best solution with the least difficulty should be used.

If a microsurgical reconstruction is selected, in addition to analyzing the three dimensional size and shape of the defect, the surgeon must assess the available recipient vessels. This assessment is done by clinical, doppler and angiographic examination. The surgeon then reviews the available donor sites which provide the tissue required and selects the most appropriate.

Often the surgeon is faced with a defect which is different from anything he or she has previously reconstructed. In this situation, it is particularly useful to use models and patterns, or go to the anatomy department, create the defect and do the operative procedure in the cadaver. If a careful step by step planning has been carried out, the surgical team can move briskly through the operating procedure with minimal delay.

The Team Approach

For the planning and execution of new and complex cases, a second surgeon is often a great asset. Complex procedures are done most effectively with two teams. One team prepares the recipient area while the other team prepares the tissue for transfer. During the transplantation, the second team is available for a back up should a major problem be encountered. With this approach, there is less surgeon fatigue and often better solutions to the reconstructive problem. Many of the problems which occur in reconstructive microsurgery are decision related and likely to occur at the end of a long procedure when a surgeon is fatigued. If there is a vascular complication after 10 hours of surgery, and a change of operative plan is required, a fatigued surgeon is not as likely to make as good a decision as one who is relatively fresh.

Pedicle Preparation

Although the technique of microvascular anastomosis is well established and frequently described, there has been little emphasis on the technique of preparing the pedicle itself.

Eye loop magnification with high resolution optics of 2.5–4.5 power and high intensity lighting is necessary for adequate visualization of the pedicle.

In each free tissue transfer and each recipient site, there is often a preferred location for identification of the pedicle. The surgeon should begin at this location and then work proximally and distally, separating the pedicle from its surroundings.

Extremity vessels do not normally become obstructed with movements of the extremity because they are surrounded and supported by fatty connective tissue. If the pedicle is dissected with a layer of fat and the venae comitantes left on the artery, the pedicle is less likely to obstruct by kinking and twisting in the recipient site. A skeletonized vessel, particularly a vein, is prone to obstruction through twisting or folding. However, leaving fatty connective tissue on the pedicle may make it more difficult to trace the vessel.

There are a number of ways of managing pedicle side branches. Hemoclips may be applied and are particularly fast and useful. However, if not applied carefully, they will come off or cut the side branch and unwanted bleeding will occur following the transfer. The alternate to clips is the more time consuming ligation with 6-0 to 8-0 sutures. For small branches, a bipolar cautery with jeweller's forceps is the preferred technique. For any of these techniques, the side branch should be divided just beyond its attachment to the main artery, but not so far removed that a blind pouch is created. Great care must be taken that the side branches of the venae comitantes are not inadvertently avulsed, producing an obstructing interstitial hematoma. If a tear is placed in a fragile vena comitans, it should be repaired with micro sutures.

Following the anastomosis, the management of the pedicle is most important. If the pedicle is obstructed by a tight skin closure, by being twisted, or by being draped over a hard object such as a tendon or bone, slowing of flow leading to anastomosis thrombosis is likely to occur. Correct pedicle length is often difficult to determine. A pedicle tends to appear shorter than it really is until the anastomosis is completed and distended by blood. The pedicle should be sufficiently long that it does not have to be stretched to reach the anastomosis. However, excessive pedicle length will produce kinking.

Anaesthetic Considerations

Anaesthesia should be administered in a manner which maintains a normal blood pressure and a good peripheral perfusion. In most non-microvascular procedures, a short period of hypotension is well tolerated by the patient and is not destructive to the operation. However, in the patient with microvascular anastomoses, uninterrupted perfusion with a normal blood pressure is necessary or anastomosis thrombosis will likely occur. Therefore, the fluid volumes must be managed carefully with a tendency to over-transfusion. Blood loss in a long procedure can be deceptively large, as it occurs gradually, slowly and persistently, without any dramatic sudden loss. Monitoring with arterial and central venous lines, hourly urine output and intermittent blood gas and hematocrit evaluations are necessary. If the patient becomes hypothermic, particularly if a transfer to the leg or arm is being done, reactive vasospasm in the extremity will decrease blood flow and may result in anastomosis thrombosis. In order to maintain body temperature, the patient should be placed on a heating blanket, given warmed IV solutions and ventilated with heated and humidified inspired gases. Room temperature control should be maintained at a level which is warm but tolerable for the operating personnel. The patient must be kept in a warm condition in the recovery room as post operative shivering may cause vasoconstriction and shunt blood away from the periphery. To prevent pressure sore problems, a double operating room mattress is used and a sheepskin is placed between the patient and the heating blanket.

The anaesthetic may be general or regional. Regional anaesthetics have the benefit of a vasodilatory effect, but the nature of the procedure or the duration of it may limit its applicability in the individual patient. For a general anaesthetic, the agents should be selected by the anaesthetist on the basis of agents which will not be harmful with a prolonged duration of use, which will not produce cardiac depression, and which allow a prompt reversal of anaesthesia and a quiet return to the awake condition. An agent which produces peripheral vasodilation and subsequent hypotension is not wise, as it will produce vasodilation in all of the patient's vessels except those upon which the surgeon is working. Vessels which have been dissected and are subject to intermittent surgical stimulation have a tendency to vasospasm which will overcome the vasodilating effect of the anaesthetic. These vessels require a good perfusion pressure which occurs only if the patient is normotensive.

Postoperative Monitoring

The most consistently reliable means of monitoring the circulation to a free tissue transfer is by visual observation of the clinical parameters of circulation. Although there has been an extensive effort in the last decade to develop monitoring devices which can evaluate flap circulation, none, except for temperature monitoring, has enjoyed general acceptance. Temperature monitoring of digital replantations and toe to thumb transfers is a reliable way of assessing the volume of blood flow. Because the digit or toe is surrounded by cooling room air, if circulation slows or stops, there will be a prompt drop in the surface temperature. Transfers which are partially buried or lie on a large warm surface area do not show the same temperature response to circulatory changes and so temperature monitoring in skin flaps is not a reliable indicator of circulatory impairment.

For free skin flaps, the color, capillary return, and tissue turgor are the most reliable clinical signs. It is important that the nursing staff be trained to note subtle changes in these clinical signs and record the signs on a flow sheet. At the first sign that there is a change in one of the clinical signs, surgical staff should be notified in order that they can assess the problem. Frequently, a decrease in perfusion is caused by compression from a hematoma, tissue swelling or a tight dressing. Systemic factors such as a drop in the patient's temperature or blood pressure may also decrease flow. With prompt recognition, these factors can often be reversed to prevent the continued decrease in circulation which may lead to thrombosis of the anastomosis.

Microsurgical Instrumentation

There is a plethora of microsurgical instruments available for preparing vascular pedicles and doing microanastomoses. The surgeon should use the ones with which he or she is most comfortable. The microsurgical tray should have a minimum of different types of instrumentation. A complex setup which has a half dozen different types of jeweller's forceps, all of which look alike to the nurse, will frustrate the surgeon and nurse alike. However, there should be at least two types of fine forceps available: a pair of fine tipped jeweller's forceps which are used for the anastomosis, and a pair of heavier forceps, with micro teeth, serrations or other pickup shape on the tips, for the coarser handling of the pedicle. Two needle drivers should be available, one for heavy needles and one, with fine tips, reserved for very fine needles. With experience, each surgeon will develop a preference for a particular style and size of needle driver. Micro scissors, both spring and regular configuration, and a range of vascular clamps should be available. Most surgeons find a double vascular clamp on a bar to be a useful means of holding two vessel ends in proper approximation when initiating the vascular repair.

Part I
Tissue Transfers

Skin Flaps

The ability to transfer tissue based on microvascular anastomoses has created a revolution in reconstructive surgery. The microvascular transfer of a skin flap is the prototype for all other free tissue transfers. The publications of Daniel, Taylor, Harii and O'Brien introduced the concept of a 'free skin flap' based on microvascular anastomoses. After the initial enthusiasm for cutaneous free tissue transfers, interest shifted to the transfer of muscles with or without their accompanying cutaneous flaps. It became apparent that muscle transfers often had a more vigorous blood supply and a longer, larger vascular pedicle than cutaneous flaps. In many situations, this muscle with attached skin flap, the musculocutaneous flap, is preferred to the cutaneous flap.

The advantages of cutaneous flaps are that they are soft and durable and provide a good cosmetic reconstruction. The final size of the flap is predictable, susceptible only to generalized weight gain or loss, whereas a muscle flap undergoes significant atrophy in the first year. The skin flap tolerates ischemia better than muscle, is more likely to recover after re-exploration of an anastomosis thrombosis, and develops more reliable vascular connections with its bed. However, when a skin flap with its thick bed of poorly-vascularized fat is transferred to an area which contains significant bacterial contamination, it may not resist infection as well as a muscle transfer.

The limiting factor in selecting a skin transfer is the availability of donor sites. A donor site for a skin flap is suitable if it contains a reliable pedicle which perfuses the area and if removal of the flap is functionally and cosmetically acceptable. The ideal donor site is one that can be closed directly and leaves a scar which is well hidden during most social activities. The closure of the groin flap is an exellent example of a flap site which leaves a scar that can be well hidden even under a bathing suit. On the other hand, when the donor site requires a split thickness skin graft for closure in a visible area, as occurs with the radial arm flap, the donor site becomes less desirable.

A skin flap may contain an axial cutaneous artery, as found in the groin and scapular flaps, or it may be supplied by a vessel which does not run in the flap but supplies branches to the overlying skin, as in the dorsal foot and radial arm transfers. These cutaneous branches may lie within a loosely defined connective tissue or within a fascial septum.

I have chosen four different skin flaps for inclusion in the book. They are the groin, scapula, dorsal foot and forearm flaps. The groin flap is little used except for buried contour reconstruction but has an important historical place in the development of skin flaps. The scapular flap will provide the answer to many if not most skin coverage problems. However, when a particularly thin or innervated skin flap is required, the dorsal foot and forearm flaps will provide the solution. There are other skin flaps which are available and not described in this book. They include the scalp, delto-pectoral, lateral thoracic, medial and lateral arm, saphenous, thigh and hemi-pulp flaps.

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Chapter 2. Groin Flap

After McGregor and Jackson introduced the groin flap in 1972, surgeons became more aware of the benefit of including a specific artery within the tissue being transferred. As a pedicled flap, it became the work horse for coverage of upper extremity soft tissue defects, and as a free tissue transfer, it broke new ground in reconstructive surgery [2].

The groin flap provides a large piece of skin and subcutaneous fat. The size of flap available depends upon the patient's build. A number of authors have reported flaps surviving that were over 30 cm in length and 15 cm in width. The donor site scar is excellent as it can usually be closed directly by undermining the abdominal skin and flexing the hip. This procedure may produce a spread scar but it will be well hidden under the bathing suit area. However, the disadvantages of this flap are many. It is particularly bulky in its medial half and not suitable in a fat person. The pedicle is small and short and there are many anatomical variations to the vascular supply. The color of the flap is pale and yellowish when applied to the face and will carry pubic hair on its medial aspect.

Its present day applications include coverage of soft tissue defects and contour reconstruction as a buried flap, particularly in the face. In many areas of the body, other flaps are preferred for soft tissue coverage. Often, a myocutaneous flap will be favoured because it is easier to elevate and has a longer, more reliable pedicle than the groin flap.

Vascular Anatomy

The vascular pedicle for this flap employs one of two possible arteries and one of four possible veins. The flap may be based on the superficial circumflex iliac artery (SCIA) or the superficial epigastric artery (SEA). The variations in the origin, route and distribution of these two arteries may confuse the surgeon. In Harii's clinical experience with 87 groin flaps, there was a common arterial trunk of the SCIA and SEA 29% of the time and, in the remainder of cases, they had separate origins. Harii recommends using the common trunk, if available, or using the SCIA as the pedicle unless the SEA is larger (20%) and then he would use the latter (Fig. 2-1 c) [3, 5, 7].

The SCIA usually takes origin from the anterolateral aspect of the femoral artery, 2–3 cm below the inguinal ligament (Fig. 2-1 A). It runs laterally superficial to the iliacus fascia in the fatty lymphatic tissue found in the femoral triangle. In passing laterally, it runs in a line towards, away from, or parallel to the inguinal ligament [6]. At the medial border of the sartorius muscle, it usually divides into two branches, either of which may be dominant. The superficial branch remains above the sartorius fascia and continues laterally, supplying skin up to and beyond the anterior superior iliac spine. The deep branch pierces the sartorius fascia at its medial border and passes on the deep surface of this fascia to the lateral border of the muscle (Fig. 2-1 b) [1, 3]. Here it exits the fascia 1–4 cm below the ASIS and runs laterally superficial to the fascia lata, supplying skin in the region of the ASIS and laterally. The deep branch also gives off muscle branches to the sartorius. If a long groin flap is required, it is necessary to include the deep branch in the pedicle. In one fifth of cases, the SCIA originates from a branch of the femoral artery, such as the deep circumflex iliac, medial circumflex femoral, or deep or superficial pudenal arteries. Taylor, in 100 dissections, found the SCIA to be present and 1 mm or larger in diameter 98% of the time [9].

The superficial epigastric artery (SEA) usually arises from a location similar to that of the SCIA. It passes superiorly and laterally, superficial to the inguinal ligament, and remains medial to the anterior superior iliac spine, to supply an area of skin above the territory of the SCIA. In view of the dissections and clinical experience of Harii and Taylor & Daniels, it is apparent that the territories of these vessels overlap and the most dependable approach to taking a flap from this area is to plan the flap axis through the centre of both vessels' territories. The largest artery to be found at surgical dissection is