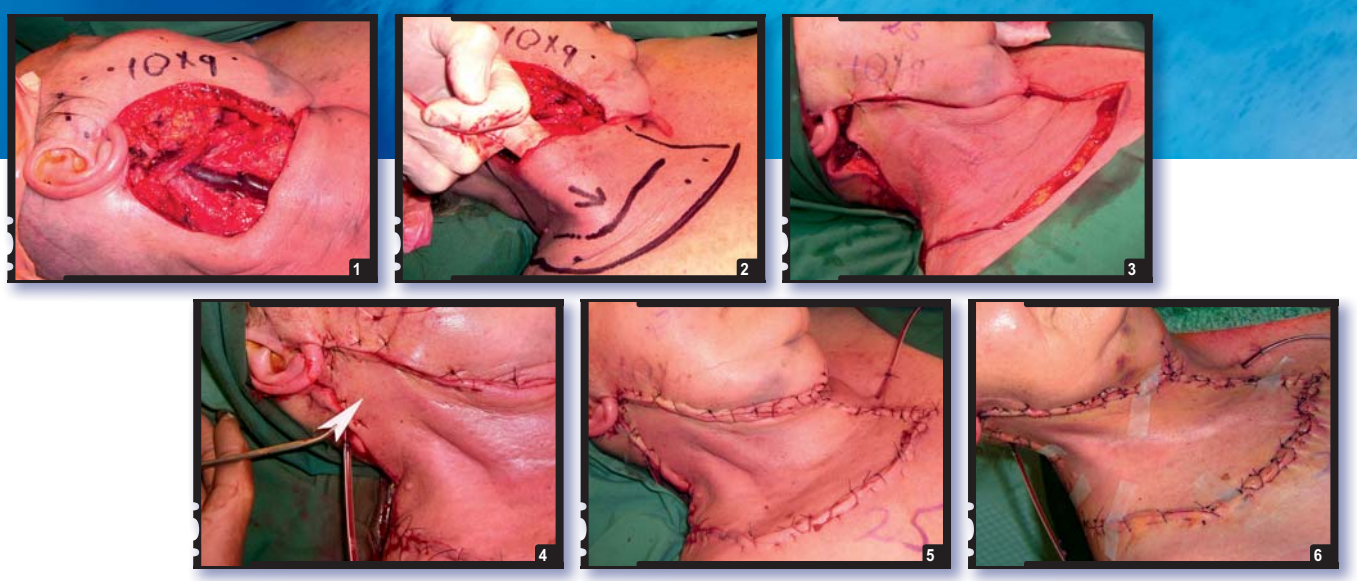
The Keystone Perforator Island Flap Concept



Felix Behan • Michael Findlay • Cheng Hean Lo

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The Keystone Perforator Island Flap Concept

Reconstructive diversity

The limitless potential of the keystone perforator island flap concept

The Keystone Perforator Island Flap Concept

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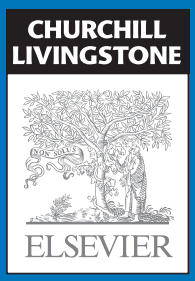

Sydney Edinburgh London New York Philadelphia St Louis Toronto

Churchill Livingstone
is an imprint of Elsevier

Elsevier Australia. ACN 001 002 357
(a division of Reed International Books Australia Pty Ltd)
Tower 1, 475 Victoria Avenue, Chatswood, NSW 2067

National Library of Australia Cataloguing-in-Publication Data

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Author: Behan, Felix.

Title: The keystone perforator island flap concept /
Felix Behan, Michael Findlay, Cheng Lo.

ISBN: 9780729539715 (hbk.)

Subjects: Flaps (Surgery)
Surgery, Plastic.

Other Authors/Contributors: Findlay, Michael William. Lo, Cheng.

Dewey Number: 617.952

Publisher: Sophie Kaliniecki
Developmental Editor: Neli Bryant
Publishing Services Manager: Helena Klijn
Project Coordinator: Geraldine Minto
Edited by Carolyn Pike
Proofread by Kerry Brown
Illustrations by Joseph Lucia of Lucia Diagraphics
Cover, internal design and typesetting by Lamond Art & Design
Index by Forsyth Publishing Services
Printed by 1010 Printing International Ltd, China

Foreword by Wayne A Morrison

Now you see it—now you don't. Felix Behan, Michael Findley and Cheng Hean Lo fill impossible holes with local manipulations that defy immediate explanation. Leaving no secondary defect, it is difficult to surmise the design or even source of the flap. These flaps, called 'keystone' because of their arch form, are essentially fasciocutaneous islands from immediate adjacent territories designed in the axis of the dermatomes to capture underlying perforators and neurocutaneous connections. Typically, the flaps move as V–Y advancements or island transpositions but, remarkably, the secondary defect, which is often larger than the primary defect, is able to be directly closed. This involves incision of the deep fascia, the keystone double V–Y advancement shape and the redistributed circumferential tension around the newly sited flaps.

Opportunity demands auditing and recording. Felix Behan began his research observations at the Royal College of Surgeons of England, publishing his angiotome concepts in 1973. Appointments to the Royal Marsden in London and Western General and Peter MacCallum Cancer hospitals in Melbourne afforded him the opportunity of a lifetime for performing, observing and recording his cutaneous reconstructions for cancer and trauma. One of the pithy quotes that precedes each chapter of the book reads 'Insight plus hindsight equals foresight' and aptly fits Felix's evolution of the keystone concept.

The book is full of mind-boggling photographs of giant holes and flap outlines that the uninitiated could only assume are destined for failure. Photography for plastic surgeons is the department of great expectations.

The first reports of these procedures produced healthy scepticism, doubters and non-believers. To understand how to do these flaps is not simple. To mobilise half of someone's face on a few semi-mystical perforators in the bold anticipation that the tissue will move sufficiently to cover an awesome hole is not for the faint-hearted. Short of an apprenticeship with the master, this book is the next best thing.

The book commences with an introduction and a detailed discussion of the fundamental vascular anatomy of the integument, followed by the design principles of the keystone technique. From there onwards it is a photographic album of before, during and after shots of every conceivable defect involving all zones of the body; a treasure trove of ideas and delights. Each region is the subject of a chapter and each includes anatomical details of the relevant perforator system. Separate chapters are allocated to melanoma defects, radiation injury and trauma. Each illustrated case concludes with a TLC (time, life quality, complications) box. To see such spectacular results one after another without complications using design principles that, at first glance, seem counter-intuitive evokes green fingers or a lucky surgeon. But the authors have harnessed chaos using art, science and courage to develop a new concept for the transfer of tissue that is reliable and reproducible.

It is a long time since a new paradigm has appeared in reconstruction. The keystone flap allows perforator concepts to be used without the need to isolate the perforator as an axial flap, reducing operating time and technical demands. In many situations, it eliminates the need for microsurgery. It reconstructs 'like with like' and radically changes the surgeon's reconstructive mindset from distant to local options. It brings back the creativity and excitement of the art and craft movement in plastic surgery that has largely been lost with the microsurgical era. By reading this superb guidebook, you too will have the confidence and the urge to take the keystone perforator island flap principles into the trenches and the marketplace where the battle is to be won.

Professor Wayne A Morrison AM MD BS FRACS
Director, O'Brien Institute, Melbourne

Foreword by Peter C Doherty

Medical advances come about in different ways. The greatest public attention tends to be focused on the generally laboratory-based discoveries that are recognised by Nobel Prizes. Harald zur Hausen (Nobel Prize 2008), for example, established the link between human papilloma virus and cancer of the cervix, a finding that led others to develop a protective vaccine. No reasonable person could doubt that this is a great achievement of enormous human benefit. But there are so many other developments, often incremental in nature, that also make life better for millions of people and which are never celebrated in such a public way. Where, might we ask, is the Nobel Prize for the artificial hip? Is the problem that too many were involved? Nobel Prizes go to a maximum of three people. Could it be that this life-enhancing technology reflects the intelligent persistence of a spectrum of surgeons, bioengineers and even entrepreneurs who persisted in the long term?

Even if they don't win many Nobel Prizes, surgeons do sometimes enjoy great public acclaim. The drama associated with the transplantation of both cadaveric and artificial hearts made the names of Christiaan Barnard and Michael DeBakey familiar to many, at least for a time. Most of the advances in surgery that deliver enormous human benefit, though, fail to engage the attention of the media, though they do make massive contributions to the restoration of function and the alleviation of pain. These surgical pioneers proceed carefully, often by incremental steps that depend on persistence, insight, continued critical evaluation and the courage to try something new and different.

The present technical manual by plastic surgeons Felix Behan, Michael Findlay and Cheng Hean Lo describes just such an advance. Lavishly illustrated with an accompanying DVD, they detail the keystone perforator island flap principle for restoring the integrity of the outer integument following otherwise disfiguring cancer, or other surgery. Operating from the central idea that it is necessary to preserve the integrity of the dermatome with its innervation and vascularisation, the essential steps are clearly laid out and explained so that other, experienced practitioners can follow.

Rather than hunting for perforators with a Doppler audio sound prior to approximating surgical transfers, the approach detailed here has been described aptly by leading international microsurgeon Professor Fu Chan Wei: 'Felix, what we do, you do in freestyle'. In other words, there is an air of spontaneous improvisation in dragging tissue from point A to point B, with all its neural, autonomic, lymphatic and vascular support intact. In addition, these procedures that mimic nature can be completed in a half to a third of the time required by conventional microvascular repair. The resultant shorter theatre times benefit the elderly, in particular. Overall, this book makes an important and substantial contribution to the art and science of surgery.

Peter C Doherty PhD
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1996 Nobel Laureate for Physiology or Medicine

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Preface

The keystone perforator island flap represents the culmination of more than 30 years of research and operative experience by its originator, Felix C Behan. It evolved out of a clinical need for a universal locoregional flap option, solving the many problems experienced in free tissue transfer. This minimally invasive technique, providing reliable and cost-effective locally matched tissue for reconstruction of wide-ranging fasciocutaneous defects, is evolving. The benefits of this approach, especially with its low morbidity in our ageing population, are reflected in its increased acceptance within the surgical community and its adoption in numerous centres worldwide. The first publication of this technique, titled 'The keystone design perforator island flap', occurred in the *ANZ Journal of Surgery* in 2003. During this time, improved understanding of flap anatomy, physiology and vascularity has been the basis of its application in numerous body regions, with various design variants. As a result, the keystone perforator island flap concept has evolved beyond the simple geometric design inherent in its name. These keystone principles can be applied to effect reliable wound closure using geometry and designs specific to the surgical needs, whatever the site and clinical situation. The reliability of these flaps and the vascular changes observed in the clinical environment in many cases has brought into question many of the edicts we have accepted historically in our understanding of flap vascularity and physiology based on cadaveric studies. Hence, the experience gained from the use of this flap in over 3000 clinical cases over 16 years is presented here in a single text for the first time.

The aim of this book is to demonstrate the versatility and clinical applications of the keystone perforator island flap technique. As with an instruction manual, the reader may 'flick through' the book and be fascinated by the various operative series that demonstrate examples from a wider spectrum of clinical applications. Alternatively, the text can be read from front to back cover to study the finer details of perforator anatomy and applied flap physiology, including more complex case studies. It is incredible how our initial concept of using the dermatomes to assist flap design has evolved into an improved understanding of the numerous *perforator zones* throughout the body. This has been the basis of new flap developments (e.g. the omega variant keystone flap), with ongoing success of this approach.

As a teaching aid, an accompanying DVD demonstrates video footage of procedures cross-referenced in the book. In this way, the book is well suited to the inexperienced and the experienced surgeon alike. The chapters on technique (Chapter 3), upper and lower limb (Chapters 5 and 7), and melanoma reconstruction (Chapter 8) are great starting points for a broad but simple understanding of the technique. The chapters on the anatomy and applied flap physiology (Chapter 2), and head and neck reconstruction (Chapter 4) are designed to highlight the more complex features of these flaps and their variants.

The last decade has seen the emergence of improved techniques for the in-vivo assessment of vascular flow within flaps, including computed tomography angiography, laser colour Doppler ultrasound, thermal, and indocyanine green perfusion imaging modalities. Hopefully, these imaging techniques will provide unequivocal answers as to why these flaps are so reliable and heal so well. We hope that readers will see this book as the pioneering text in keystone perforator island flap surgery and use it as an inspiration to apply its principles and develop innovative techniques throughout their careers.

Felix C Behan
Michael Findlay
Cheng Hean Lo

Acknowledgments

First, I acknowledge my co-authors, Michael Findlay and Cheng Hean Lo, for their clinical, scientific and technological input in producing this tome.

Throughout my career, I acknowledge the following people and organisations: Brian Cortice, from Brisbane, who, without his input and refinement in surgical repair, the hemming suture would not have evolved; the plastic surgical training I received in Melbourne, where, thanks to a reference from the late Peter Grant, I worked with Sir Benjamin Rank at the Victorian Plastic Surgical Unit, who introduced me to plastic surgical reconstruction; Don Marshall, who taught me the refinements in surgical reconstruction; my colleague, the late Alan McLeod, who introduced me to the London surgical scene, with Ian Wilson, Charlie Westbury and Henry Shaw, all part of the St George's/Westminster/Marsden group; the Bernard Sunley Research Fellowship at the Royal College of Surgeons, without which I would not have come upon the idea of fascial-based flaps designed as angiotomes for reconstructive purposes; the Charing Cross Hospital and mortuary department, who made cadaver specimens available for educational purposes; my colleagues at the Western Hospital—Trevor Jones, Graeme Thomson, Chris Haw and the orthopaedic team—and the Peter MacCallum Cancer Centre—Michael Henderson, David Speakman, John Spillane, Simon Donohue and Mikki Pohl—without whom the referral base of cases would not have been as comprehensive; Professor Gordon Clunie, Bob Thomas, Andrew Sizeland and Steve Chan, who, without their academic input, this project may not have reached fruition; the registrars in training and junior staff for their scientific input in article and textbook preparation; and Margaret Clancy, to whom I am indebted for educational and secretarial support.

Internationally, I acknowledge Professor Bill Kuzon of Michigan, who provided editorial assistance on my first paper on the keystone flap in 2003. He saw the value of this reconstructive tool in patient care, in parallel with the microsurgical development which has been part of the Melbourne scene since Ian Taylor's first microsurgical reconstruction in the 1970s. Professor Wayne Morrison of the Bernie O'Brien Microsurgical Institute was part of the editorial process in my first keystone publication in the *ANZ Journal of Surgery*. Also, Andrew Burd of Hong Kong, former editor of the *Journal of Plastic, Reconstructive and Aesthetic Surgery*, and Jacques Baudet from Bordeaux, on the European scene, have been very supportive in the development of this idea.

I can only mention in passing the college libraries and hospital departments, who have all been most helpful. My photographic development has improved thanks to the team at the Peter MacCallum Cancer Centre.

At a personal level, my late father, when he was on the Senate of the University of Queensland, actively supported postgraduate study and was a factor in this encouragement.

In conclusion, the final acknowledgement goes to my wife, Mariette, and my children, Laurent, Amandine and Thibault, for their individual contributions, IT support and tolerance of the impositions I have placed on them throughout a surgical career. At a clinical level it was my wife, Mariette, who made the observation some years ago when doing my dressings that 'your wounds are healing better now' after I commenced using island flaps of the keystone type all over the body. It was only in retrospect that the improved vascularity was recognised as a feature of the keystone island flap concept, underlining its value as a reconstructive tool.

Felix C Behan

I owe a debt of gratitude to: Felix Behan for having the patience to put up with a trainee and now colleague who continues to ask questions and suggest that the current understanding is insufficient; Cheng Hean Lo, who has made an invaluable contribution to the text and helped us to maintain a sane collaborative environment that I hope will continue long into the future; my wife, and children Aly and Will, for putting up with all the late nights and weekends away from home during the preparation of this manuscript; and, finally, to all the patients who put their lives and well-being in our hands and agreed to allow us to catalogue their progress before, during and after their surgery so that we might teach others and improve our own technique. We hope their efforts will result in better understanding of this technique and its more widespread application as a useful option in fasciocutaneous reconstruction.

Michael Findlay

I thank my family for consistently supporting me in all my achievements: my parents, who made immense sacrifices in migrating to Australia; my wife, Elaine, who is my tower of strength; and my delightful daughter, Erica, who supports me in her own little way by surprising me with her ever-evolving curiosity of the world.

I am grateful to my co-authors, Felix Behan and Michael Findlay, for making this journey most enjoyable.

Felix Behan, Michael Leung and Heather Cleland are influential mentors in my surgical career. Their passion for their work, teaching, fortitude and willingness to lead by example are to name only a few of the attributes I have benefited from and aim to emulate.

Cheng Hean Lo

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Section 1

The Fundamentals of Keystone Island Flaps

Chapter 1

Introduction to the keystone island flap

A simple solution to many reconstructive problems

Observation is the basis of scientific advancement.

Sir William Osler (1849–1919)

The keystone island flap is a unique reconstructive tool in its versatility, reliability and simplicity.

Since the development of the keystone island flap by Behan in 1995 (Behan 2003), this useful technique has become a workhorse for locoregional fasciocutaneous reconstruction in numerous body regions, both in our Victorian centre and, more recently, in centres around the globe (Pelissier et al. 2007a, 2007b). The attractiveness of locoregional reconstruction has always been offset by the need to be familiar with a very large number of named flaps in order to confidently undertake locoregional flap closure in most instances. The keystone island flap offers a solution to this dilemma by providing a single reliable flap that is easy to design, elevate and inset to effect rapid fasciocutaneous closure in most regions of the body. The technique is relatively easy to learn and forms an ideal starting point for the trainee or new surgeon undertaking their first locoregional reconstructions. In experienced hands, it permits the closure of large fasciocutaneous defects. It requires very little post-surgical care comparative to other approaches and, therefore, is not only of use in developed countries but also in developing countries where specialist postoperative nursing care is not routinely available.

Interest in this flap is increasing. The reasons stem not only from the intrinsic utility of the technique, but also from how it meets the needs of today's patients and the time-strapped surgeons who care for them. Worldwide, populations are ageing (UN Department of Economic and Social Affairs 2010). In Australia, the proportion of the population aged over 65 years is projected to almost double and those aged 85 years and over to quadruple by 2056 (Australian Bureau of Statistics 2008). These population changes place unprecedented demands on health budgets, emphasising the need for cost-effective patient management. Furthermore, multivariate analysis has revealed patient age to be a significant risk factor for medical complications following oncological surgery (Audisio et al. 2007). These two factors, in combination, place additional demands on today's surgeon to provide tissue reconstruction with minimal morbidity (and mortality) to patients and to deliver these outcomes in a cost-effective manner.

Free-tissue transfer represents a technologically advanced treatment option developed to provide reconstruction where the use of locoregional flaps alone is inadequate. The more recent developments of perforator flap and free-style free-flap surgery have further glamorised an already exciting reconstructive approach and, as a result, today's reconstructive surgical trainees are well-versed in microsurgical reconstruction at the expense of their training in locoregional flap reconstruction. Most reconstructive microsurgeons use about a dozen free flaps (with variants) as the basis for the majority of their reconstructions. This somewhat formulaic approach has simplified modern-day core microsurgery but has made training in advanced

locoregional reconstruction (>500 individual flaps described to date) less appealing. Despite free-flap reconstruction being achievable in increasingly elderly and infirm patients, microsurgical reconstruction is costly for the patient's health, the surgeon's time and the health department's budget. Free-tissue transfer is associated with long operative times, prolonged in-patient stay, hyperdynamic postoperative circulatory management with concurrent risk of cardiac compromise, anticoagulation with its potential risks and poorer aesthetic outcomes when compared with locoregional fasciocutaneous reconstruction. Octogenarians with head and neck cancer suffered a higher incidence of medical complications after microvascular reconstruction, even after controlling for the level of preoperative comorbidity using the American Society of Anesthesiologists' (ASA) score (Blackwell et al. 2002). In addition, the duration of intensive care requirements was prolonged. As such, free-flap surgery is ill-suited to meeting the needs of our ageing populations except in specific instances (e.g. composite tissue or bony reconstruction).

The keystone island flap offers a single fasciocutaneous flap that is suitable for use in nearly every region of the body to achieve rapid and reliable fasciocutaneous coverage with minimal morbidity to the patient, good cosmesis and good quality of life. As such, it is well suited to meet the needs of reconstructive surgeons into the future and should appropriately limit the use of free-flap reconstruction to defects unsuitable for locoregional reconstruction and assist in the management of free-flap morbidity by assisting donor site closure.

Skin grafting is an invaluable tool, particularly where very large epithelial loss occurs, such as in burns or large pretibial ulcers. However, its use can be problematic, especially in the lower limb. For less extensive defects, the keystone island flap can provide an attractive alternative to solve the morbidity associated with skin grafting in the lower limb. Postoperative immobilisation to enhance skin graft take puts the patient at risk of venous thromboembolism, pressure ulcers and deconditioning, with loss of independent mobility (Budny et al. 1993). It ties up a valuable hospital bed with significant economic cost to the health system. Keystone island flap closure of lower limb defects can often be undertaken in the ambulatory setting, making it suitable for widespread application; it also avoids the morbidity of an additional donor site. The simple design facilitates re-excision for incompletely excised lesions, and the full-thickness fasciocutaneous closure is comfortable for most patients and has improved aesthetics compared with other reconstructive approaches. As with all islanded flaps, the design must incorporate underlying perforators or neurovascular support. Therefore, flap elevation over subcutaneous bone necessitates extension of the flap beyond the bony margin to capture perforators from the surrounding fascia and muscle. As with other flaps, the stretching of keystone flaps over sharp edges or surfaces (e.g. over the pretibial border to supply the contralateral side of the leg) should be avoided. The benefits of the keystone island flap are summarised in Box 1.1.

BOX 1.1 Advantages of the keystone island flap

- Simple to design
- Robust vascular supply
- Reliable healing
- Short operative time
- Minimal patient morbidity
- Relatively pain-free surgery
- Good aesthetic outcome
- Cost-effective wound closure

THE DEVELOPMENT OF THE KEYSTONE ISLAND FLAP

The keystone island flap represents the culmination of nearly four decades of research and clinical reconstructive surgery. Following on from the work of Manchot (1889) and Salmon (1936), Behan undertook cadaveric injection studies (using resin and radiocontrast dye with xerography and histological examination) while undertaking a research fellowship at the Royal College of Surgeons of London in 1972. These studies demonstrated that the system of axial vessels to the integument can supply the regions of adjacent axial vessels via *linkage vessels,* as summarised in Figure 1.1 (Behan & Wilson 1973). This led to the development of the concept of the *angiotome**, which is a section of skin and underlying tissue that can be islanded on a single axial vessel so as to incorporate the integument normally supplied by that vessel and, if necessary, adjacent regions that are supplied from the central axial vessel via these linkage vessels (Behan & Wilson 1975). Thus, flap elevation within the angiotome for a given perforator permits the reliable elevation of a flap supplied to its periphery through linkage vessels from the feeding perforator to adjacent vascular territories within the flap that have lost their natural perforator supply. It is presumed that dilatation of the linkage vessels, along with an increase in their calibre and number, occurs following vascular delay, but an angiotome does not normally require vascular delay for tissue survival (although delay can maximise tissue survival/recruitment of

* Angiotome was coined by Behan as an extension of an existing term—the angiotome—'a segment of the vascular system of the embryo' (Dorland 1994), as a means to describe a segment of tissue (cut as a flap) that can be supplied by a single axial vessel (perforator or direct) either directly or via communications to adjacent territories (increasing the flap's size).

adjacent vascular units). In Chapter 2 we will discuss how the physiological regulation of cutaneous blood flow can be manipulated to maximise the angiotome of a given vessel and, therefore, increase the reliability of locoregional flaps.

In defining the angiotome concept, this early work permitted an improved understanding of how tissues can be either islanded or raised as free flaps while maintaining adequate blood supply to the integument. Some of the regions assessed include those that have become well-known flaps today, such as the superficial temporal artery (laterally based or total forehead flap; Fig 1.2), internal mammary perforator and thoracoacromial axis (deltopectoral flap), and deep inferior epigastric artery perforators (hypogastric flap, or more commonly known as the DIEP flap; Fig 1.3).

Unlike Manchot (1889) and Salmon (1936), who focused on the axial vessels themselves, the identification of linkage vessels and the development of the angiotome concept permitted the subsequent development of a number of direct and perforator-based fasciocutaneous flaps. Islanded flaps, such as the Bezier flap (French curvilinear V–Y island advancement) and the perforator-based keystone island flap, incorporate the principles of the angiotome to facilitate perfusion to the margins of the flap. Since then, further use of the keystone island flap in compromised tissues has allowed the development of the *immediate vascular augmentation concept (IVAC)*. These important vascular studies and their conclusions predate the subsequent vascular studies of others, including Cormack and Lamberty (1984a, b) and Taylor and Palmer (1987), as well as the angiosome concept. The *angiosome*, as the region of tissue autonomously supplied by a single vessel, has proven to be an invaluable concept for the description of blood supply to all the tissues of the body. However, the *angiotome* concept answers the most important clinical question for reconstructive surgeons; namely, what amount of tissue can be islanded on a single source vessel? The technique of keystone island flap elevation seeks to maximise the size of the

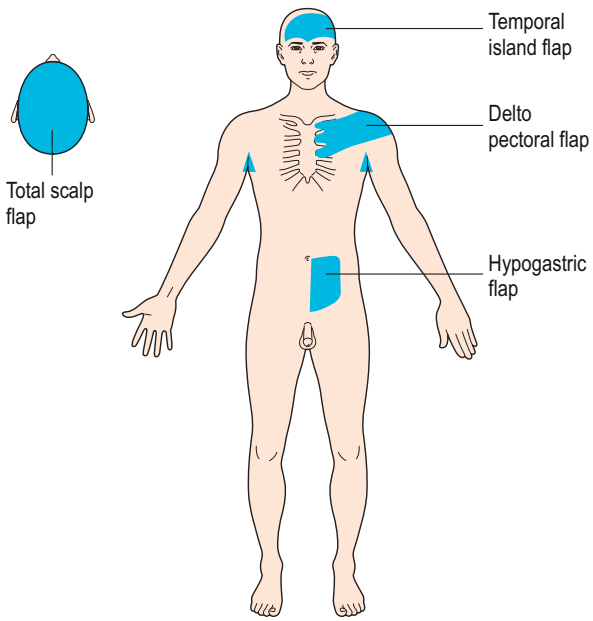


FIGURE 1.1 Original diagram of the body indicating the sites of various perforator or direct vessel fasciocutaneous flaps investigated by Behan as part of his angiotome concept in 1973. The hypogastric flap has subsequently been renamed in clinical use as the deep inferior epigastric perforator (DIEP) flap, used extensively for breast reconstruction. This is the first anatomical study of the basis of this popular perforator flap. The temporal flap was used to facilitate scalp replantation clinically.

(Reproduced with permission from Behan & Wilson 1973.)

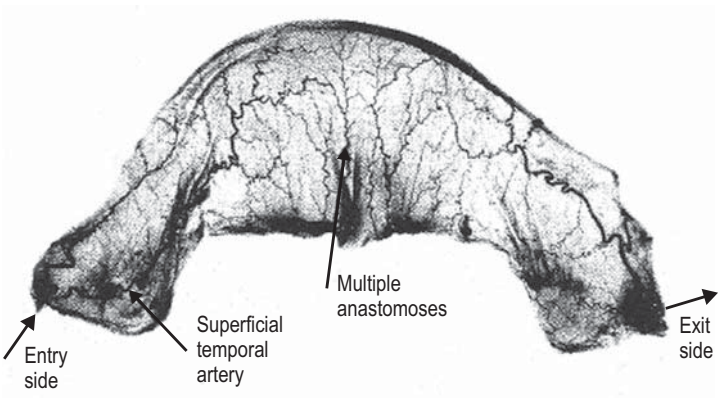
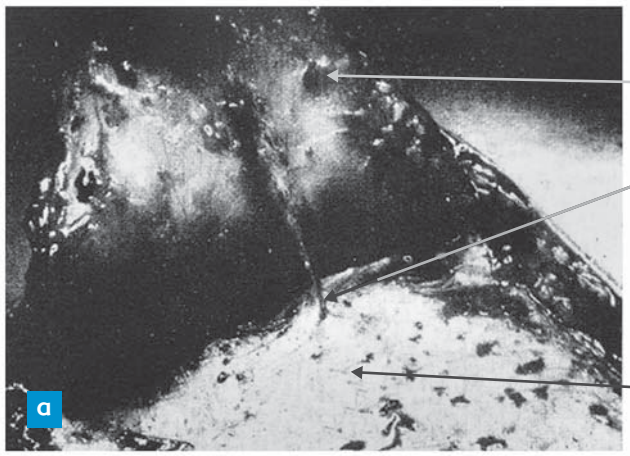


FIGURE 1.2 The total forehead flap—superficial temporal artery

Injection of 50% micro-opaque dye in the anterior branch of the superficial temporal artery at various stages of filling, demonstrating the principles of angiotomes and linkage vessels.

(Reproduced with permission from Behan & Wilson 1973, Figs 3–5.)



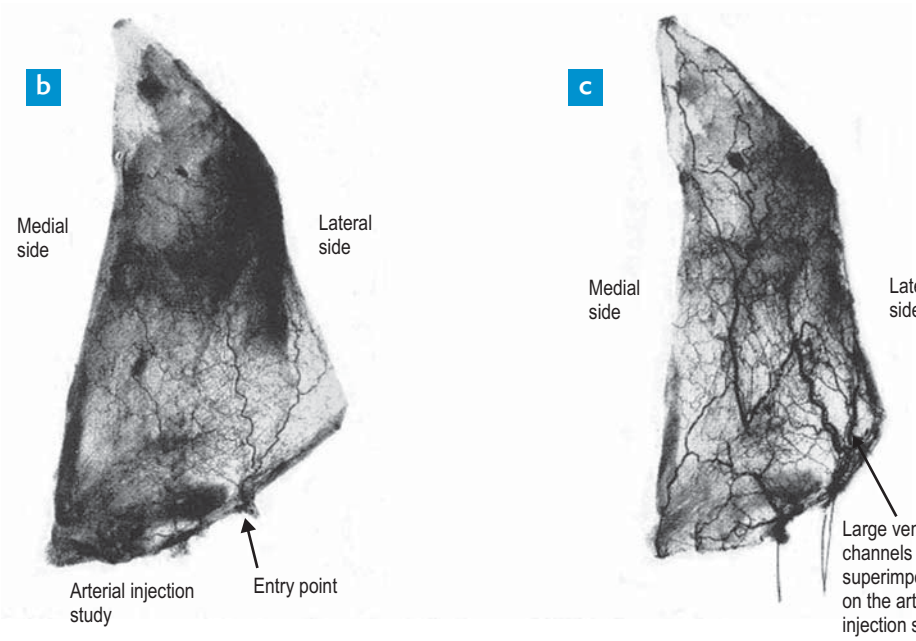


FIGURE 1.3 The hypogastric flap—deep inferior epigastric artery perforator

(a) Dissection of the hypogastric flap revealing a deep inferior epigastric perforator emerging from the anterior rectus sheath. **(b)** Arterial and **(c)** venous injection studies of the hypogastric flap showing the density of vessels.

(Reproduced with permission from Behan & Wilson 1975, Figs 7–9.)

angiotome from any perforator and augment this supply by providing additional (conjoint) neurovascular supply and superficial venous drainage. A comparison of the angiotome and subsequent angiosome concepts is presented in Table 1.1. The immediate vascular augmentation concept observed with islanding results in an islanded angiotome (keystone or other variants) that augments perfusion.

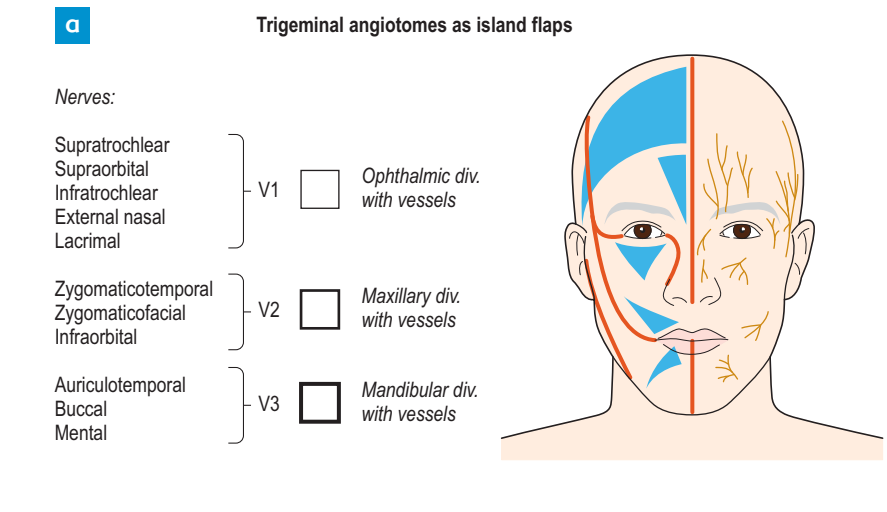
Cadaveric studies are useful to provide clues as to how tissues are perfused in vivo, but recent advances in computerised tomographic (CT) angiography have highlighted what almost 35 years of experience has provided clinically; namely, that cadavers are a poor substitute for the careful assessment and cataloguing of perforators, vascular patterns, skin and soft tissue viability during the raising of angiotomes (as various forms of island flaps) in live patients as part of tissue reconstruction (Rozen et al. 2009). The insight Rozen and colleagues (2009) gained through cadaveric studies has been applied in a progressive manner to raise larger and larger direct and perforator-based island flaps in various regions of the body (often along the lines of the dermatomes of the body, as discussed in Chapter 3).

A preliminary series of locoregional flaps (approximately 200 cases) was published in 1992 and an analysis of this series provided the basis upon which the current concept of the keystone island flap is founded (Behan 1992). Fasciocutaneous island flaps were used in various anatomical regions throughout the body (Fig 1.4). Having identified a reliable method for the elevation of islanded flaps so as to incorporate sufficient perforator or direct vessel support, the focus shifted to the geometric design of the flaps in order to facilitate primary closure and to optimise aesthetics.

The Bezier or French curve flap was published in 1995 (Behan et al. 1995). It was introduced to deal with elliptical defects that are not closable by direct apposition. Developed from similar underlying principles to the keystone island flap, the Bezier flap is an elegant extension of the V–Y advancement principle

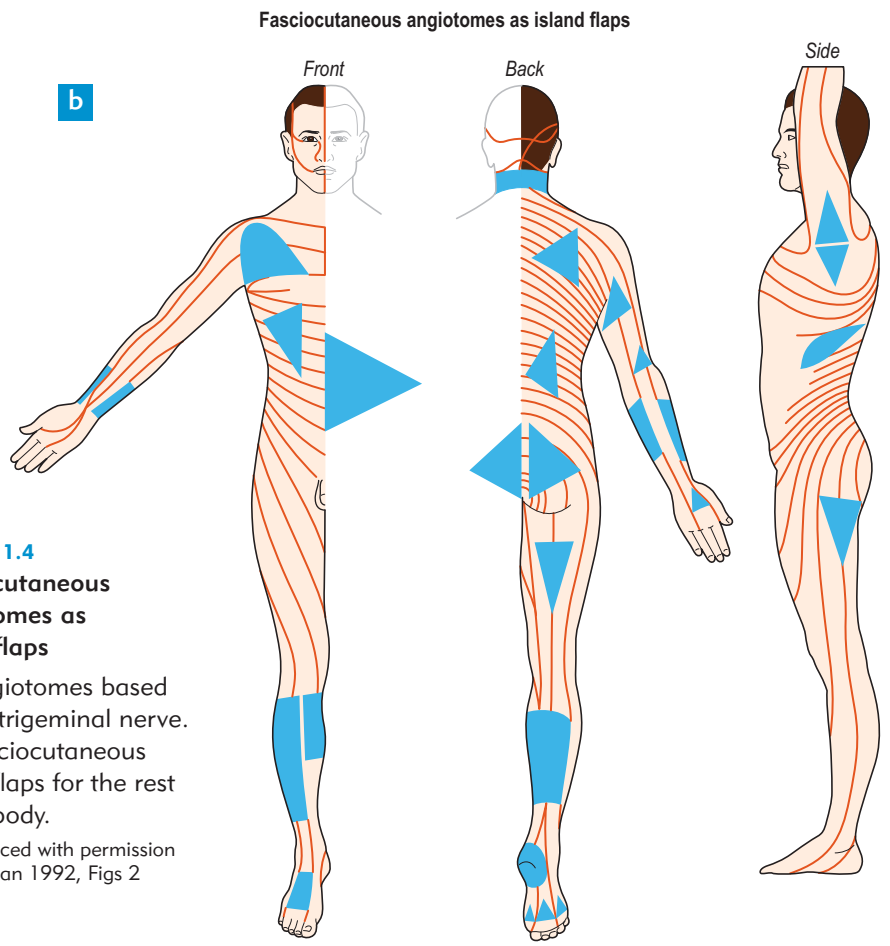
TABLE 1.1 Angiotome versus angiosome

	Angiotome	Angiosome
Definition	An area of skin that will survive when cut as a flap supplied by an axial vessel (with its blood supply) extended by its communication with branches (or links) from an adjacent vessel.	A region of tissue supplied by a single axial (or direct) vessel without capture of linkage (or choke) vessels.
Published	Behan & Wilson1975	Taylor & Palmer 1987
Clinical utility	Defines how tissue flaps can be raised on perforating or direct vessels	Defines autonomous blood supply for tissues of body



Major island flaps	
Forehead	11
Eyebrow	1
Eyelid	6
Temple	3
Ear A	4
Ear C.F.	4
Nose	12
Lip	7
Chin	1
Neck ant.	2
Cheek	1
Total	**53**

Total to the 1st April 1992. Excluding small or minor flaps with subcutaneous pedicles



Major island flaps	
Neck	2
Scalp	13
Axilla	5
Chest wall	3
Abdomen	1
Upper limb:	
– upper arm	9
– forearm	6
Back	5
Hand	40
Sacral area	16 + 16
Lower limb:	
– thigh	3
– leg	24
Foot	10
Total	**137 + 16**

Total to the 1st April 1992. Excluding small or minor flaps with subcutaneous pedicles

FIGURE 1.4
Fasciocutaneous angiotomes as island flaps

(a) Angiotomes based on the trigeminal nerve. **(b)** Fasciocutaneous island flaps for the rest of the body.

(Reproduced with permission from Behan 1992, Figs 2 and 8.)

(i.e. limited in terms of advancement). The gentle curve of the Bezier flap uses Langer's lines to minimise the visibility of scars and maximise the aesthetic result.

In subsequent years, the design of the Bezier flap evolved. The gentle curve of this design was retained at the wound margin, but it was identified that having two regions for V–Y advancement and moving these areas further away from the long axis of the wound would provide improved tissue laxity and greatly aid the primary closure of larger defects. This resulted in an arc of tissue being raised on underlying perforators; hence, it was initially coined the 'arc' flap.

It was renamed a keystone flap** due to its resemblance to the keystone of archways. A keystone is the central, apical, wedge-shaped stone of Roman (and other) arches that lies in such a manner as to provide arch support through the action of gravity and friction. This architectural development facilitated the building of multistorey structures, including the Colosseum (Fig 1.5). In an analogous manner, the shape of the keystone island flap seems to lock into the defect and provide structural advantages for wound closure, employing double V–Y advancement (Dieffenbach).

In 2003, the keystone island flap concept—as the keystone design perforator island flap—was first published (Behan 2003). Described as a curvilinear-shaped trapezoidal design flap, it fits well into body contours. Since that time, it has been used extensively to effect wound closure in various regions of the body. The ease of use, short operative time, minimal morbidity, reliable healing and avoidance of costly and morbid free-flap reconstruction in our ageing population has led to an explosion in the use of this technique in recent years, both in Australasia and overseas.

** The term 'keystone' was suggested as a more appropriate descriptive term for Behan's arc flap by Mr Alan Breidahl, a Melbourne plastic surgeon.

It is also gaining popularity in the management of defects following radiotherapy. Tissue reconstruction in irradiated fields remains a complex and challenging problem, marred by poor wound healing, flap necrosis and eventual wound breakdown. Local flap reconstruction is usually to be avoided following radiotherapy; however, the reliable healing and robust vascular supply seen with keystone island flaps resulted in the keystone island flap being used extensively for the closure of irradiated defects (Chapter 9). The experience with keystone island flaps in irradiated defects was published in 2006 (Behan et al. 2006) and demonstrated the utility of these flaps for reliable wound closure in irradiated fields. Since then, the excellent wound healing demonstrated with these flaps in irradiated fields has made their use commonplace for this purpose.

The purpose of this text is to assemble, in one book, an easy-to-understand guide to the development, design and surgical application of the keystone island flap. The extensive use of clinical defects, followed by intraoperative series of photographs and videos, is deliberate so as to maximise transfer of the relevant concepts. Additional information, such as the history, neurovascular anatomy, reconstructive alternatives and technical refinements, are presented in boxes for the interest of the reader.

In the following chapters we will discuss in detail the design elements and flap physiology upon which the keystone island flap is based. Following a general discussion of the flap and the basis of how it works, we will look at specific defects in various regions of the body and examine how keystone island flaps have been used to close these defects successfully. Following this, the use of the keystone island flap for specific surgical entities, such as melanoma and trauma, is addressed. A summary can be found at the end of each chapter, which may be of use where the reader wishes to gain a

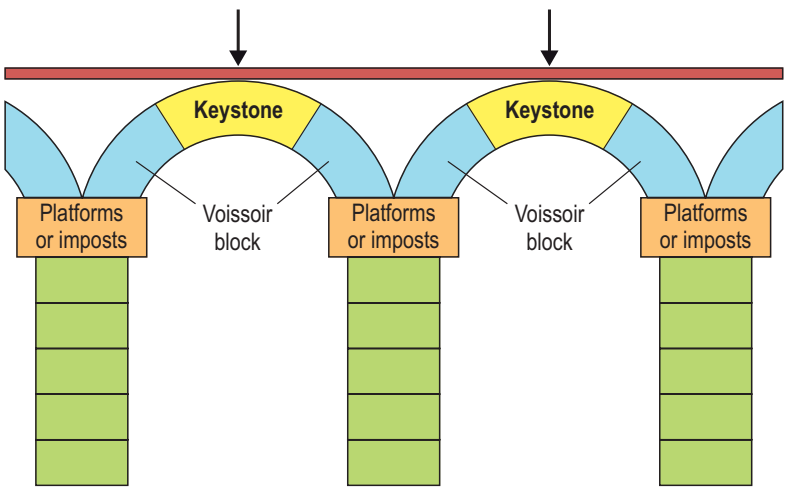


FIGURE 1.5 Architectural nomenclature
(Reproduced with permission from Behan 2003, Fig 2.)

rapid understanding of each of the chapter's contents. Surgeons new to locoregional flaps will find Chapter 3 on the design and technique of keystone flap elevation to be invaluable and should then consider reading Chapters 5 and 7 on the lower and upper limbs as starting points for the incorporation of this technique into their own practice.

In the current era of microsurgical free-tissue transfers, free perforator flaps and free-style free flaps, the aim of reconstruction should be more than soft tissue coverage. The reconstructive surgeon must not lose the art of functional aesthetic reconstruction, focusing on aesthetics and quality of life. We are firmly of the belief that free-tissue transfer has revolutionised reconstructive surgery and will maintain an invaluable role in patient care for many years to come. However, we challenge today's reconstructive surgeon to have equal familiarity with locoregional reconstruction, such as the keystone island flap, as a less invasive, simpler and more time-efficient means to achieve similar results in many instances. We see the keystone island flap and microsurgical free-tissue transfer as complementary reconstructive techniques, which should be part of any reconstructive arsenal in the 21st century.

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