Science Principles for Plastic Surgery

12

Geranium purpureum

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Science is a way of thinking much more than it is a body of knowledge

(Carl Sagan)

The important thing is to never stop thinking

(Albert Einstein)

In support of the two famous quotes above, Sir Harold Delf Gillies once remarked that plastic surgery was a constant battle between beauty and blood supply. Beauty is something we should never stop thinking about as plastic surgeons, because it is everywhere we look for it and the beautiful normal in form, function and the human aesthetic is our goal. The blood supply to vital organs, bones, soft tissue integument and the skin are quintessentially what define plastic and reconstructive surgery as a science and a craft. Add to this mix the art and vision of an artist, together with good listening skills, compassion and connectedness of a good doctor; that is all you need.

12.1 Blood Supply of Skin

An understanding and appreciation of the circulatory system is mandatory for primary and secondary healing. Historically the pioneering work of Salmon et al. defined the anatomical basis of blood supply to the body. By modern standards this is an integrated network of vasculature coursing in a predictable pattern from named source arteries through muscles and fascia to the subdermal plexus and then in reverse through the venous tributaries back to the named source veins. The heart, that reliable, resilient and marvellous pump organ, is what drives it all [1].

William Harvey in 1628 defined the modern concept of blood supply.

Tomsa (1873), Manchot (1889) and Salmon (1936) were the early contributors to the understanding of the blood supply of the skin, by painstaking dissection and observation. Salmon from Paris introduced the classification of direct and indirect cutaneous arteries. The latter being the musculocutaneous, neurocutaneous and fasciocutaneous perforators, so important in today's local and loco-regional flaps. Salmon's writing considered the surgical implications and introduced the concept of cutaneous arterial territories, each with a certain autonomy. Many of these early publications were written in German or French and were not readily available to the English-speaking surgeons.

Gillies et al. found a practical if not altogether reliable way to close war wounds with random pattern flaps of a limited length to breadth ratio. Some authors have criticised this approach with a retrospective smugness, but we believe it simply a case of appreciating historical developments that have all contributed to the rich tapestry of plastic surgery concepts.

Taylor et al. confirmed the findings of Manchot and Salmon in the twentieth century and described the Angiosomes, a series of anatomical three-dimensional vascular territories. These are governed by reliable principles:

1. The connections between adjacent cutaneous arteries are either by true anastomoses, without change in caliber, or by reduced-caliber choke anastomotic vessels

2. One adjacent anatomical/cutaneous perforator territory (skin module) can be captured with safety radially in any direction on the perforator at the flap base.
3. Most muscles span two or more angiosomes and are supplied from each territory, one is able to capture the skin island from one angiosome via the muscle supply in the adjacent territory.
4. Vessels follow the connective tissue framework of the body.
5. Vessels radiate from fixed to mobile areas.
6. Vessels hitchhike with nerves.
7. Vessel size and orientation are a product of tissue growth and differentiation.

Vessels obey "The Law of Equilibrium" (If one vessel is small, its partner is large to compensate and vice versa.)

8. Vessels have a relatively constant destination but may have a variable origin.
9. The vessels form a continuous unbroken network.

The Angiotome concept closely matches the angiosome theory. Behan and Wilson started work on this in 1973 whilst research fellows in London. The *angiotome* is an area of skin that survives when cut as a flap, supplied by an axial vessel extended by its communication with branches from the adjacent vessel. The concept emphasises the role of the dermatome and the intrinsic neurocutaneous vascular supply of the human skin. This is essential to the planning of bespoke keystone perforator island flaps (KPIFs).

The fasciocutaneous island flaps that Behan was using to cover compound lower limb fractures in the 1990s developed into the keystone perforator island flaps. Serendipitously he combined the dermatome pattern of design with the concept of angiotome vascular perfusion.

Essentially a dermatome associated with somite development is an area of the skin supplied by a spinal nerve. If a spinal nerve is to develop from the notochord (primitive streak area), it must have an arteriovenous support network for this autonomic-somatic neural complex. The basic embryological principle is confirmed. The neurovascular structures subsequently become arborized, which account for their distal perfusion from minute vascular links.

Lymphatic development must also accompany such arborisation with development and growth. This simple aide-memoire of a dermatomal link, based on a fascial support without skeletonizing the perforator source, allows the accompanying lymphatic and autonomic fibres to be retained.

Finally, there are humoural factors (nitrous oxide), which also operate within this scheme [2, 3].

12.2 Local Flap Principles

1. Elliptical excision and sliding flap repair is the basis of all traditional local flap repairs.

2. Limberg (1946) described as a paradox the principle that in order to close a skin defect, a nearby triangle of healthy skin equal in size to the defect is discarded.
3. Burow and Bernard both applied this principle to their triangular excisions.
4. Tension in a flap decreases the blood flow in the flap.
5. Even if this decreased flap blood flow is not enough to cause skin necrosis, atrophy will occur at a subcutaneous level, to produce a depressed scar at the distal end of the flap.
6. David Tolhurst (1988) described an Atomic System for classifying flaps where he compares all flap repairs to the nucleus and electrons of an atom.
7. The nucleus lists the tissue components of the flaps (e.g. skin, fat, fascia, muscle …).
8. The outer shell system lists the various flap characteristics (e.g. skin or non-skin blood supply, axial or random pattern, form, destination and special preparation).

12.3 Tolhurst's Atomic System for Classifying Flaps

Klaassen et al. Simply Local Flaps page 25, Fig. 12.1, Springer International Publishing AG 2017.

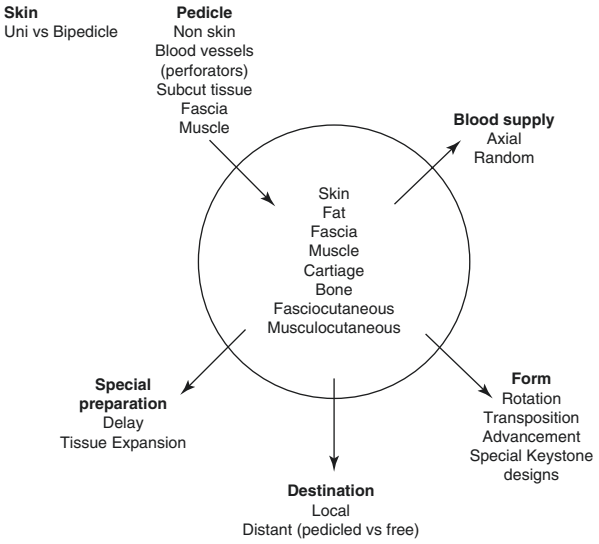

Fig. 12.1 The atomic system for classification of flaps by David Tolhurst (with his express permission)

12.4 Wound Healing

Wound healing involves a complex physiological process at a cellular level involving stem cells, inflammatory cells, matrix molecules, cytokines and various mediators. There are four distinct phases of healing:

1. Coagulation phase (immediate)
2. Inflammatory response phase (48–72 h)
3. Proliferative phase (days 4–21)
4. Maturation phase (up to 1 year)

The proliferative phase includes the formation of extracellular matrix (ECM), angiogenesis and re-epithelialisation. Fibrillar collagen is the main structural component of the ECM responsible for both elasticity and strength in an intact scar. Collagen type I and type III are recognised as the main building blocks of a scar and although type III increases more than type I in the early stages of healing, it decreases to normal levels during the final maturation stage.

12.5 Hypertrophic and Keloid Scars

Fibroblasts and diseased stem cell fibroblasts contribute to the clinical problems of hypertrophic and keloid scars. The spectrum from physiologically normal to keloid scar is a continuous one determined by genetically influenced control pathways involving apotosis, growth factors and angiogenesis. Fibroblasts transform into myofibroblastics which produce the collagen types I & III, cytokines and influence wound contraction. Various forms of collagenase and proteinase influence the final scar formation. Some patients have a propensity to develop hypertrophic scars. Those areas of the body that are prone to hypertrophic scars, are: anterior chest and deltoid regions.

12.6 Management Options for Hypertrophic and Keloid Scars (Mild—Severe)

Micropore tape compression (for 12 weeks).
Silicone gel/sheeting.
Intralesional corticosteroid/5FU/Interferon.
Topical cryotherapy.
Intralesional cryotherapy (Cryoshape probe)—*the most efficacious*.

LASER ablation.
Surgery + immediate radiation.

12.7 Surgical Site Infection

Exam candidates should have a full appreciation of the implications of Surgical Site Infection and be prepared for infection related questions.

We recommend you be familiar with recent published reports and recommend the 2017 Wisconsin Division of Public Health Supplemental Guidance for the Prevention of Surgical Site Infections: An Evidence-Based Perspective [4].

The Core Section describes recommendations that should be applied to all surgical procedures.

The candidate should be familiar with:
The size and evidence for the problem
Antibiotic prophylaxis
Glycaemic control
Normothermia
Oxygenation
Skin prep with alcohol-based antiseptics
Potential risk with administration of blood products during arthroplasty surgery
The role of Microbial biofilms.

12.8 Skin Microbiology

There is a balance between normal skin flora and innate immunity. 90% of the resident aerobic skin flora is *Staphylococcus epidermidis*. It is generally regarded as a commensal but it can also act as a pathogen. *Staphylococcus aureus* is the most common pathogen isolated in surgical site infections.

$$\frac{\text{Dose of bacteria} \times \text{virulence}}{\text{Resistance of the host}} = \text{Risk of Surgical Site Infection}$$

The equilibrium is broken.

Remember that severe inflammation can be sometimes mistaken for surgical site infection. This is particularly common with sutures used for local flaps that are left in-situ for more than 2 weeks.

The dose of bacteria is significant for inoculation. Dr. Martin Robson showed that the critical figure for infection is 10^6 organisms per gram of tissue [5].

12.9 Other Important Scientific Concepts

Primitive Streak the faint streak which is the earliest trace of the embryo in the fertilized ovum of a higher vertebrate.

Telomere: a compound structure at the end of a chromosome.

Apoptosis: the death of cells which occurs as a normal and controlled part of an organism's growth or development. Also called programmed cell death.

Atrophy (of body tissue or an organ): is a wasting away, especially as a result of the degeneration of cells, or becoming vestigial during evolution [6].

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