Hand Transplantation

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Springer

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Library of Congress Control Number: 2006928862

ISBN-10 88-470-0373-3 Springer Milan Berlin Heidelberg New York
ISBN-13 978-88-470-0373-6 Springer Milan Berlin Heidelberg New York

Springer is a part of Springer Science+Business Media
springer.com

Cover design: estudio Calamar, Barcelona, Spain
Typesetting: Graphostudio, Milan, Italy
Printer: Grafiche Porpora, Segrate (Mi), Italy
Printed in Italy

"to my wife Mariagrazia and
my sons Matteo, Michael and Pietro,
for sharing all my dreams,
and
to Valter, Gianni, Domenico, heroic patients,
for their trust in me and my trust in them"

Marco Lanzetta

"to my grand children
Louis, Hugues, Alexis, Émilie, Céline, Elsa ...
dreams might come true"

Jean-Michel Dubernard

Preface

The story of this book is quite simple: after the first few hand transplants, we felt the need to have regular meetings so that our clinical experiences would be beneficially shared and serve as a basis to draw some guidelines for the future. In so doing, we soon realised that a huge amount of original clinical data and information was becoming available as we were proceeding with our operations and closely following our patients' progress and functional outcomes. Some of these data were reported in scientific articles, but to group them in a comprehensive book seemed the best way to provide a complete review of this pioneering work.

Since starting our hand transplantation programmes, we often felt we were exploring a new area of surgery without the possibility or comfort of referring to already published work to support our own decisions. Indeed, some aspects of hand transplantation required prompt decisions based solely on personal interpretation of presenting clinical scenarios. New techniques were introduced to address different needs, such as the analysis of brain remodeling using functional magnetic resonance imaging or the use of a sensory glove to precondition the patient or accelerate the recovery of sensibility. Original work included creation of a specific consent form for patients, psychological tests for candidates and a comprehensive scoring system for assessing clinical outcome. There was the need to establish a grading system to evaluate acute skin rejection and clear criteria to select ideal candidates. From a legal point of view, there were no criteria for dealing with persons carrying two different sets of fingerprints. From an insurance perspective, there were no criteria as to how the disability of these patients would be revaluated after the hand transplant.

Clinically, the most challenging issues have been identifying the best immunosuppressive drug regime and understanding how acute rejection develops and how to reverse it. Use of an additional distant skin island allograft resulted in better rejection monitoring, at the same time avoiding the need to take multiple biopsies from the hand. Nerve regrowth and excellent sensibility/motor recovery was one of the most important results in hand transplantation, and leading experts in peripheral nerve regeneration suggest a scientific explanation. Rehabilitation of the transplanted hand has been very demanding for both therapists and patients, and specific protocols had to be implemented.

As the hand is only one of the composite tissues currently transplanted in order to correct disabilities or deformities, we include chapters on all the other types of non-life-saving allografts, including the face, knee joint, uterus, abdominal wall and larynx.

We are honoured to have such a great number of internationally renowned personalities share their experience and knowledge in this book; their contributions have made it the most complete work available on hand and other composite tissue allografts. We hope it will serve as a useful guide for those desiring to launch their own composite tissue transplantation programmes or to those who simply wish to read about the current state of the art of this new and exciting field.

Marco Lanzetta
Jean-Michel Dubernard

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1. Historical Remarks

Section 1-a

Cosmas and Damian Revisited

Bruce W. Conolly, Mario Benanzio

Introduction

Transplantation – that is, the transfer of tissue from one location to another – as a surgical procedure dates as far back into human history as cave paintings. As long ago as 8000 BC, domestic animals were castrated, initiating the physical juxtaposition of donor and recipient necessary for transplantation. The oldest surgery recorded in humans from the prehistoric archaeological records from the Bronze Age showed skulls from this time being subject to trephination: To relieve intracranial pressure, a circular disc of bone was removed from the calvaria and later replaced as an orthoptic autograft.

Myths and legends from Egypt, China, India and early Christendom illustrate transplantation, the oldest record being 2000 BC in Egypt. One Hindu text (700 BC) explained the procedure of nasal reconstruction in which, after a man's nose had been cut off or destroyed, the doctor took a leaf of a plant the size of the destroyed parts, measured a piece of the cheek of the same size, and replaced the nasal defect. On this surgical wound would be placed powder of sapanwood, liquorice root and barberry covered with cotton. As soon as the skin had grown together with the nose, the connection with the cheek was cut.

From the earliest times, medical practitioners have sought divine help in their healing endeavours. In the early Christian era, there were four patron saints of medicine, all from Asia Minor and all educated in the Greek medical tradition. They were the apostle Luke, Saints Cosmas and Damian and Saint Panteleimon. Through the centuries, they have served as worthy role models for the physicians who have invoked their aid [1].

At the dawn of the Christian era, there was the popular custom of "incubation" [2]. Sick people would visit the temples of Aesculapius to pray that the gods would heal them as they slumbered. The temple attendants would apply oil and wax to the afflicted body parts and perform surgery if necessary. This was the background of the third-century "miracle of the black leg" (Fig. 1). In the third century AD, St. Cosmas, a physician, and St. Damian, a surgeon, removed the malignant and gangrenous limb of an aged sacristan of the church. While the sacristan slept, these two doctors successfully transplanted the leg of a recently deceased Ethiopian Moor to the leg stump of the dreaming patient [3]. Whilst one brother removed the diseased leg with a saw, the other went to the pagan gladiator graveyard on Vatican Hill at the Circus of Nero where St. Peter's Cathedral now stands, exhumed the body of a recently buried Ethiopian man, procured one of his legs and returned to the church. The saints joined the Ethiopian's leg to the dying man's stump. The sacristan, on waking, discovered he had a new, healthy, although black, leg. The sacristan who lost his leg found this old leg later in the Moor's grave. Although it is unlikely that the Saints Cosmas and Damian legend was derived from historical fact, it is clear that exper-

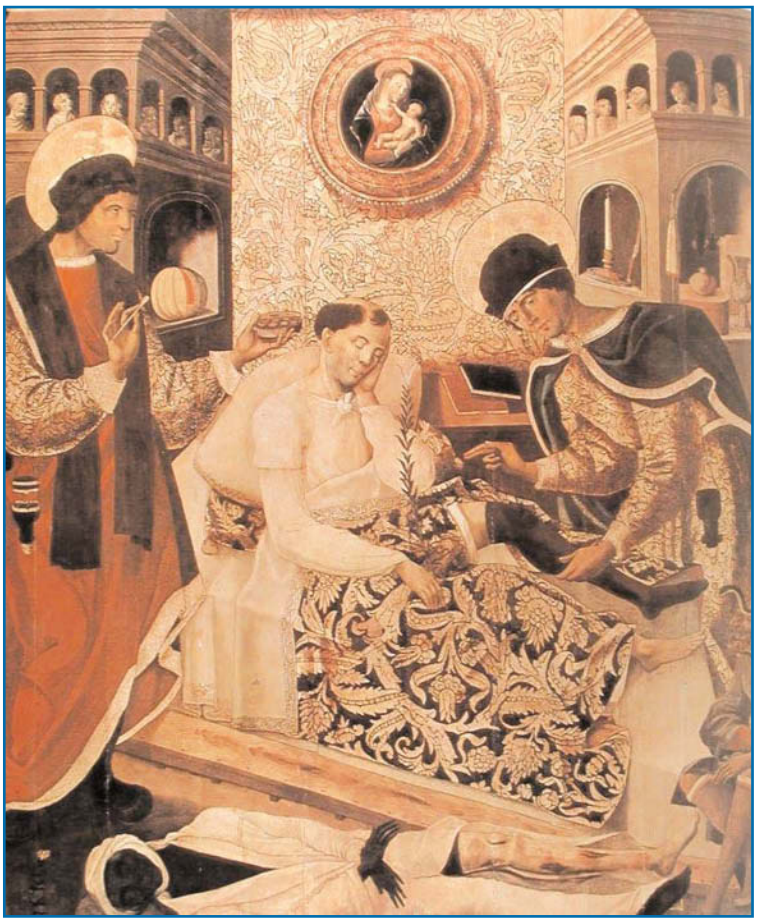

Fig. 1. Saints Cosmas and Damian, the martyred twin physicians, shown in a sixteenth-century painting attributed to Fernando del Rincon performing their most famous posthumous miracle: the replacement of a sacristan's gangrenous leg with that of a dead Negro. The Prado, Madrid

imentation with various types of transplants did persist in following centuries. There are archaeological records from Egypt, North and South America, Greece, Rome and China showing teeth transplants as early as 1000 AD.

Fifteenth to Nineteenth Centuries

Skin graft prognosis and techniques increased considerably during the fifteenth century. A popular hero of transplantation is Gaspare Tagliacozzi, a sixteenth-century surgeon who restored noses. He is a symbol of the glorious Renaissance after the darkness of the Middle Ages. The Italian poet Calenzio wrote that some slaves donated their own noses to their masters. In the eighteenth century, John Hunter [4], Scottish anatomist and surgeon (founder of experimental surgery) and the so-called father of British surgery, reported effective allografts of chicken testes and Achilles tendon autografts in other species. In 1804, Baronia performed free tendon allografts between sheep, and by 1880, stable corneal transplants in both humans and animals were recorded. By the nineteenth century, free grafts were documented of the following tissues: skin, tendons, nerves, cartilage and corneas.

Twentieth Century

Substitution of a healthy organ for a sick or damaged one has always been the dream of surgeons. Such techniques need to unite the transplant with the patient's system of blood vessels. This obstacle was overcome by French surgeon Alexis Carrel [5] who, in 1902, introduced his vascular suture method, but the initial wave of enthusiasm ran into a basic problem: the guest organ would be rejected by the host organism. The body's immunity defence mechanism react-

ed against such foreign cells and killed them. The efforts of Carrel and American surgeon Charles Guthrie is described in their work on the "transportation of veins and organs", and this served as a foundation of both vascular surgery and organ transplantation [6]. In 1905 at the University of Chicago, Carrel and Guthrie performed the first cardiac transplant in animals. The early theory regarding the mechanism of rejection was malnutrition of the grafting tissue, suggested by Paul Ehrlich in 1906 [7].

In the early 1960's cadaveric donations were thought to be impracticable and impossible and living donors were the only available source of organs for transplantation.

In 1910, Carrel noted that the physiological disturbances in transplanted organs were likely caused by biological factors. Soon after, the Viennese pathologist K. Landsteiner discovered the ABO blood grouping system that eventually led to the introduction of clinical blood transfusion. Sir Peter Medawar, in World War II, transplanted skin on badly burnt soldiers in London [8]. He understood that rejection was not due only to surgical and technical mistakes but mostly to the immune response. Without biological compatibility between the donor and the host, the transplanted organ would undergo failure. He was awarded the Nobel Prize for his pioneering work.

In 1914, the fact that lymphocytes infiltrated grafts was recognised, but it was many years before the molecular basis of T-lymphocyte activation was known as the cause of acute rejection. This knowledge of immunology led to the first successful kidney transplant between identical twins in 1954, and this initial work in the field began with the recognition that organ allografts may be transplantable. In this vein, skin grafts performed by Medawar during World War II for burn victims were successful only when performed between identical twins.

Twentieth-Century History of Organ Transplantation in Humans

In 1954, the first living related kidney transplant was performed by Joseph Murray between identical twins in Boston [9]. Over the next 25 years, discoveries in immunosuppression paved the way for a 10% manipulation of the recipient's immune system. The first successful cadaveric diseased kidney transplant was performed in 1962; in 1963, the first successful lung transplant was performed; also in 1963, the first successful liver transplant was performed by Thomas Starzl on a 3-year-old child in Denver, USA; and in 1967, the first successful heart transplant was performed. Following its discovery by Jean-François Borel in 1972 [10], cyclosporine was introduced to prevent rejection of transplanted organs by suppressing the body's immune system, which increased survival rates of transplanted organs.

History of Hand Transplantations

In 1964, a hand transplant was attempted in South America with primitive immunosuppressive agents. The transplant was rejected at 2 weeks. On 23 September 1998, the first hand transplant with early success was performed on a New Zealand patient in Lyon, France. However, the hand was later amputated in the United Kingdom in February 2001 at the patient's request. It was reported that the patient failed to follow the correct antirejection treatment and physiotherapy. In January 1999, the Louisville hand and microsurgery team in the USA carried out their first hand transplant. Their patient continues to do well, gaining strength, control and range of movement of his new left hand. In September 1999, two single hand transplants were reported from China, and since then there have been many more around the world.

Now Back to Saints Cosmas and Damian

Who were Cosmas and Damian, and why are they relevant to the history of hand transplantation? Cosmas and Damian are regarded as the most famous of all medical saints. They were Arabian twin brothers, the first children born in

a family of 7 boys in Cilicia, Turkey. Like their parents, they were strongly committed to the Christian faith. They were convinced that the Holy Spirit called them to study medicine. They practiced not only in the city of Aegea, now Ayash (Ajass), on the Gulf of Iskanderun in Cilicia, Asia Minor, where they attained a great reputation, but also travelled widely, tending not only to suffering humanity they encountered along the way but also to beasts of burden. They devoted themselves to healing rich and poor alike, accepting no payment for their medical services, thus earning their title of *anargyroi*, the "Silverless Ones" [11]. Their example established four tenets of proper conduct for the physician: to neglect no one suffering infirmity, to apply suitable treatment, to inflict no harm and not to demand excessive fees.

Artists portray them as youthful, beardless and wearing long, fur-trimmed robes and red caps (Fig. 2). They hold medicine boxes, urine glasses, mortars, salve spatulas and other items used by contemporary physicians living in the time of these artists. Although pictures of the saint healers representing Cosmas and Damian can be found in many churches, the oldest picture is said to be in the church situated in Densus. This picture is important because one of the saints holds a small portable medical pouch in one hand that seems to be made of wood, and in the other, he holds a spoon used to administer the medicine of the time, usually pills or bolus. Many saint healers have been painted in churches but they do not have such utensils.

So popular were the brothers that in antiquity, numerous Christian doctors took the names Cosmas or Damian. During the Crusades, a group of knights formed the Cosmas and Damian Order to assist ill pilgrims and to exchange prisoners of war. Among the cities selecting the brothers as patron saints are Florence, Prague, Salamanca and Essen, as well as the country of Bohemia. They became the patron saints of physicians, surgeons, barbers,

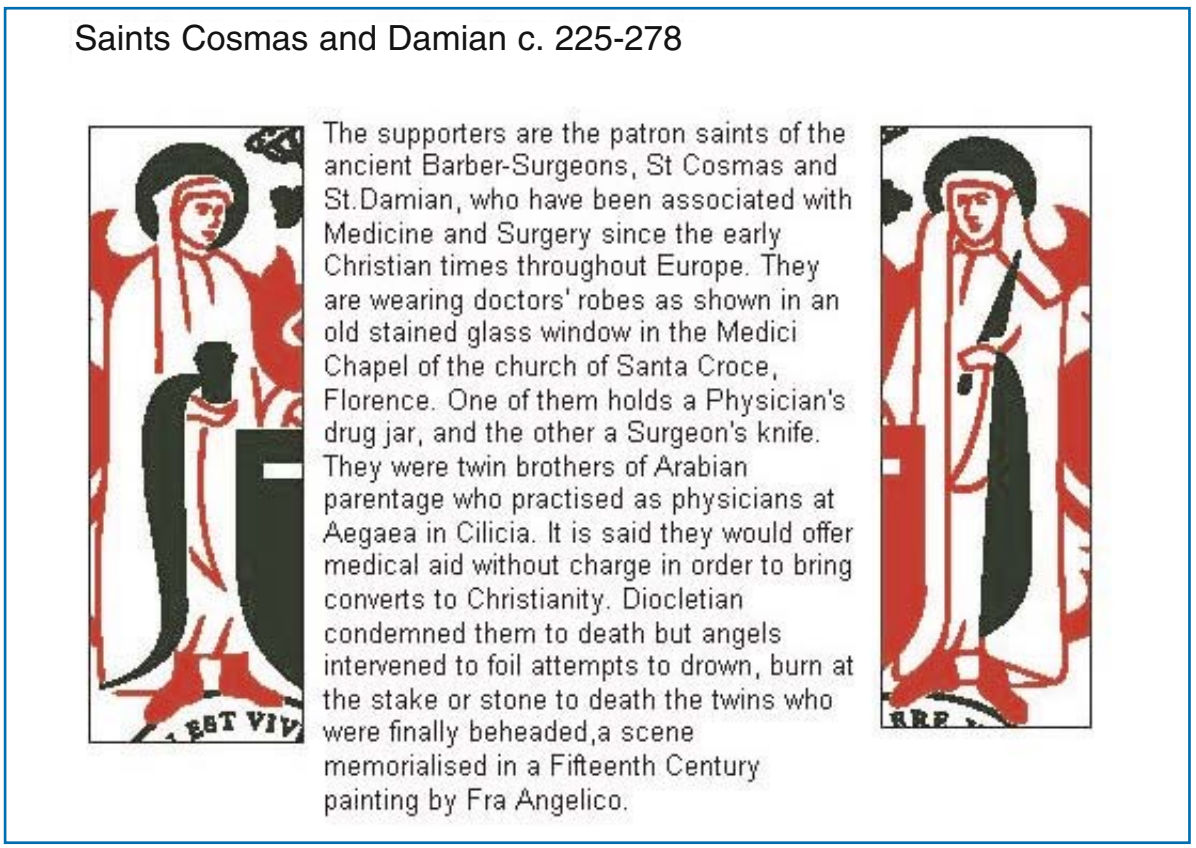

Fig. 2. Saints Cosmas and Damian from the Royal Society of Medicine Coat of Arms UK. From [3], used with permission

physicists, bakers and apothecaries, and representations of them are found in the coats of arms of medical bodies to the present day. Their numerous healing successes were regarded as miracles, and their example inspired many to embrace Christianity. The emperors Diocletian and Maximian were so concerned about the influence Cosmas and Damian were having against the ideas of the Roman Empire that when the saints refused to give up their faith, they were arrested by Lisia, the governor of Aegea, and put on trial in the court of Caesar and sentenced to death by three tortures. The first torture was being cast into the sea with their hands and feet bound. A miracle occurred as they became free, enabling them to swim to shore. The second torture was burning at the stake, but a second miracle occurred as the flames failed to burn them. The third torture was by flogging but the whips would not hit their mark. After a final demand that they renounce their Christian faith was refused, Cosmas and Damian were decapitated by the sword on 27 September, 287. Their death is depicted in the famous angelic panel in the monastery of St. Mark in Florence (Fig. 3). The holy doctors were buried in a magnificent tomb in Ciro, Syria, the home of Bishop Teodoreto, their first biographer, who eulogised them in the famous *Heroes and Glorious Martyrs* [12].

After the deaths of Cosmas and Damian, there was a continuous procession of pilgrims and sick people to visit their grave to petition them to intercede with God to heal their afflictions [13]. When Emperor Justinian (527–565) was healed of his grave and debilitating disease, he had an exquisite basilica erected at the grave site in Constantinople, and he fortified the entire city [14]. Pope Felix IV (526–530) established a church dedicated to Cosmas and Damian in the Roman Forum built by Vespasius in Constantinople [15]. It was

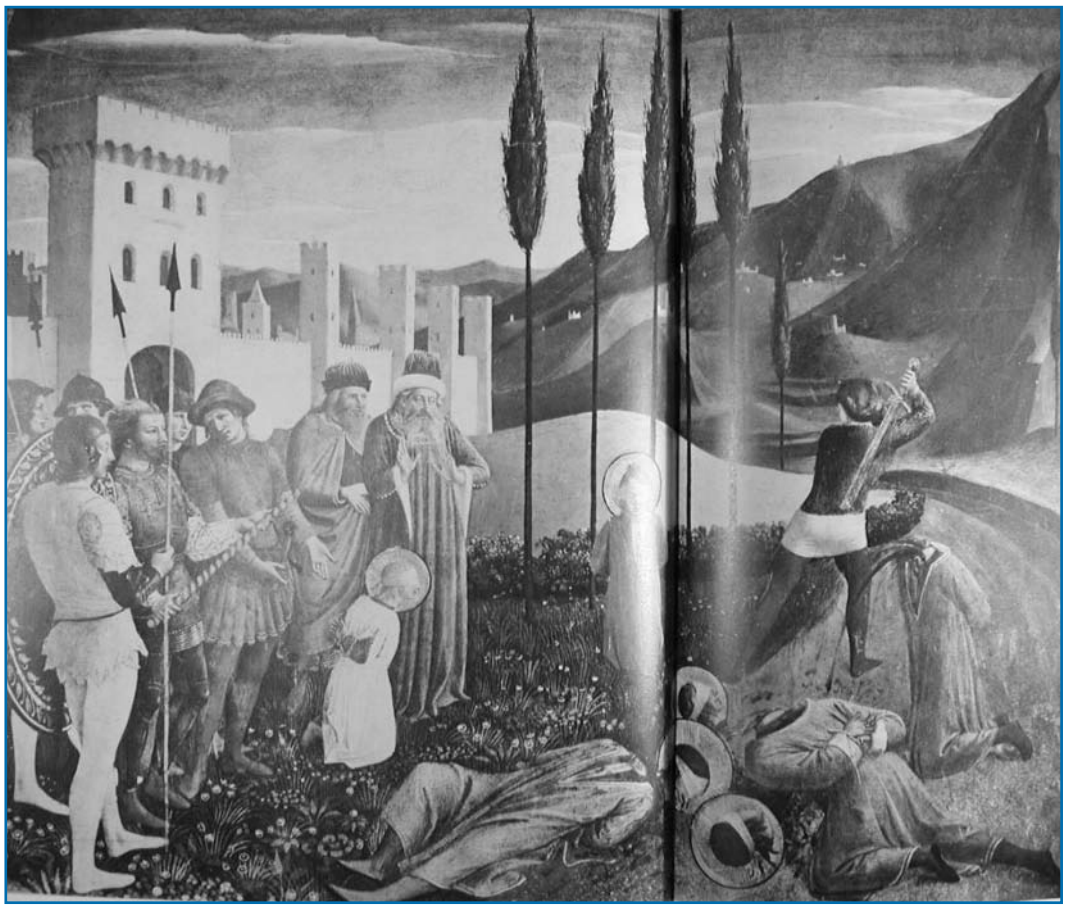

Fig. 3. The martyrdom of the sainted physicians Cosmas and Damian, as envisioned by Fra Angelico in a painting from the predella of the San Marco altarpiece (c. 1438-1440). The Louvre, Paris

here that Galen himself taught and wrote his commentaries on the Hippocratic text in 169 AD. The aps of the new basilica was decorated with mosaics that are now considered to be one of the most unique and best-preserved examples of Byzantine art. The inscription reads: "To the medical martyrs the hope for the salvation of the people". An eighth-century fresco in Santa Maria Antiqua in Rome also highlights Saints Cosmas and Damian. Hans Suss von Kulmbach, a late Middle Ages artist (1480–1522), depicts them as the patrons of doctors and pharmacists on two altar wings in Nuremberg, Germany. Fra Angelico (c. 1401–1455) painted their crucifixion as well as the famous leg transplant scene (Fig. 4). They also are shown as helpers during the plague in a painting by Titian in Santa Maria della Salute, Venice (Fig. 5). In Essen, woodcarvings of Saints Cosmas and Damian show them holding salve boxes and swords.

Cosmas and Damian are the patrons of the city of Gaeta in Italy, and it is believed, through their intercession, the city's population was spared during the eighteenth-century plague. Cosmas and Damian were also very important to the Medici family – they became the family protectors. They were more than personal symbols of the Medici because they fulfilled the purpose that all saints do for Catholics, serving as spiritual mediators or, in effect, representatives of the family in heaven. The Medici were concerned with exposing their souls to as many prayers as possible, and they had built the Medici chapel of Cosmas and Damian in San Lorenzo, Florence.

A close connection between religion and medicine existed amongst primitive peoples in early civilisations. With the spread of Christianity, medicine became the concern of the priestly cast, and one of the first principles of Christianity was the healing of the sick [1]. Investigation into natural causes of the diseased was discouraged. Treatment at the time consisted of being quiet and restful in a peaceful atmosphere, with intercession and prayer and the cult of healing saints. Churches and shrines dedicated to certain saints and martyrs became places of pilgrimage. A patron saint was regarded as having the power to relieve afflictions of a particular organ or part of the body. St. Agatha was concerned with diseases of the breast, Saints Sebastian and Roch were the saints of the

Fig. 4. Saints Cosmas and Damian, seen caring for an amputee in this late sixteenth-century painting by Ambrosius Francken the Elder, had numerous miraculous cures attributed to them and later became patron saints of the healing professions. Koninklijk Museum voor Schoen Kunsten, Antwerp

Fig. 5. Fra Angelico, in the mid-fifteenth century, depicts another miraculous cure by the martyred twin physicians in "The Healing of Palladia by Saints Cosmas and Damian". National Gallery of Art, Washington DC

plague, St. Blaze the patron saint of the throat, St. Apollonia the patron saint of toothache and Saints Cosmas and Damian the patron saints of barbers, surgeons and apothecaries. Later, the practice of surgery was forbidden to priests and therefore passed almost entirely into the hands of barbers and other uneducated men although there were always a few surgeons of high rank who attended to royalty and the nobility.

Cosmas and Damian, apart from being represented on the coats of arms of medical bodies, have hospitals, monasteries, schools and chapels dedicated to them around the world. The Society of Saints Cosmas & Damian is an Italian/American organisation formed in 1926 during a period of heavy immigration to America by many Europeans. A large group came from the beautiful coastal city of Gaeta in Italy and settled in Cambridge and Somerville in Massachusetts in the USA. These immigrants had a sense of community belonging, and a small group of women, encouraging this, met periodically to pray to these patron saints of their beloved city of Gaeta. Soon the group grew bigger and involved men, and it became a yearly festival to honour these saints in 1926. A chapel to house the life-size statues of the two saints, which had been brought from Gaeta, was built in 1940 in East Cambridge, and it underwent major renovations in 1995. The feast day of Cosmas and Damian is celebrated on 27 September.

Conclusions

The possibility of successful organ replacement has challenged men's minds through the ages: Greek Chimera, the Minotaur, the wings of Daedalus and Icarus, the dragon, the gryphon, the sphinx and the siren. The dream of the Ancients from time immemorial has been the junction of portions of different individuals, not only to counteract disease but also to combine

the potentials of different species. This desire inspired the birth of many mythical creatures, which were purported to have capabilities normally beyond the power of a single species. The modern world has inherited these dreams in the form of the sphinx, the mermaid, and the chimerical forms of many heraldic beasts [16]. The Hindu pantheon has become the object of surgical reinterpretation; the chimeric state of certain Asian gods, such as Brahma, is endowed with many arms as well as heads or faces.

It is unlikely that the legend of Cosmas and Damian derives from historical fact, but experimentation with the various types of transplants did persist in the following centuries. There is no way that the transplanted black leg could have survived when reattached to the aged sacristan. Cosmas and Damian would not have had the prerequisite vascular suture technique or immunosuppressive agents, but this legend is incorporated into transplantation medicine, if not as an actual precedent, at least as proof that the idea has existed for a long time. Transplantation existed first as a legend, but now surgery is about to make the dream come true with the advent of chemotherapy immunosuppression mercaptopurine (6-MP) in 1960, azathioprine by Joseph Murray in 1963 and cyclosporine A in 1976 [9].

Reference to Saints Cosmas and Damian even has a twentieth-century application. When a newspaper reporter asked if the Massachusetts General Hospital claimed priority for the restoration of a young boy's severed arm, the hospital spokesman referred the reporter to the Syrian surgical team of Saints Cosmas and Damian and the legend of the transplanted leg.

The dream of humankind is now being fulfilled [17]. Depicting themselves as the legitimate heirs of Saints Cosmas and Damian, fifteen centuries later surgeons of today can pursue the historiographical tradition of representing themselves as the new divine healers. Saints Cosmas and Damian are thus enrolled as allies.

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Section 1-b

Hand Transplantation as an Evolution of Microsurgery: A Logical Step Towards Better Reconstructive Options

Marco Lanzetta

Introduction

Microsurgery was developed in the twentieth century by combining techniques of vascular surgery with an operating microscope, fine instruments, microsuture and new operative strategy and techniques. The first vascular anastomosis was performed by J.B. Murphy in 1897, but Alexis Carrel [1] originated the method for triangulation of blood vessels to perform arterial and venous repairs in 1902. He performed an end-to-end anastomosis. It was in 1960 that Jules Jacobson [2], a vascular surgeon, described microsurgical anastomoses in vessels as small as 1.4 mm using an operating microscope.

A traumatic arm amputation was reattached surgically for the first time in 1962 when Malt and McKhann [3] described their experience with a ten-year-old boy, but microsurgical techniques were not used, as blood vessels were large enough to be repaired by conventional methods. In 1965, the first successful replantation of an amputated finger by microvascular technique was done by Komatsu and Tamai [4] in Japan. The first microsurgical transplantation of the great toe (big toe) to thumb was performed in April 1968 by Mr. John Cobbett [5] in England. In the 1970s, a number of surgeons, including Buncke [6], Daniel [7] and Taylor [8], opened the way to the routine use of free flaps to cover defects around the body.

Reconstructive Microsurgery Levels

Today's reconstructive microsurgery is a complex and more refined technique than the one that was employed only two decades ago. Until some time ago, microsurgery meant mainly covering a defect or replanting severed parts back where they belonged. Now, restoration of original function and aesthetic appearance are considered a must in planning any reconstructive procedure. Minimising morbidity at the donor site and selecting more sophisticated flaps for better matching with the tissues to be reconstructed is a mandatory choice. Lately, it is not unusual to take part in scientific panels or meetings about "aesthetic microsurgery". Hand transplantation, which can be included in the wider concept of composite tissue transplantation, represents one of the logical evolutions of microsurgery and seems both inevitable and scientifically justified by the initial clinical results.

Five different levels of reconstructive microsurgery can be identified, from easy to very difficult, depending on the complexity of the procedure, the reconstructive goal to be achieved and the provenience of the selected flaps. Fresh from the experimental lab, where he or she has been extensively training under the microscope to become accustomed with the likely clinical challenges, a young microsurgeon *in pectore* will be

eager to enter at least the entry level. Usually, he or she will be initially asked to deal with emergency situations needing revascularisation or replantation of body parts, so the job will be quite similar to that performed in the lab (Level 1). As the microsurgeon develops experience he or she will consider alternatives to replanting body parts back to where they originally were, as this strategy might not necessarily be ideal. In some cases, the amputated part needs to be altered, replanted in a different position or two or more parts combined to obtain a replantable unit (Level 2).

Moving to the next level will require more skills and anatomical knowledge, as flaps need to be harvested from a donor site and moved to a different body area with the intent of covering a defect or tissue loss caused by trauma or surgical removal of neoplastic lesions (Level 3). When just "covering a hole" is not enough but there is the necessity to reconstruct a specific function or restore the cosmesis of a body part as close as possible to the original appearance, then free flaps might require careful planning for selecting the most appropriate tissue(s) without leaving an unacceptable defect or unaesthetic scars. The concept of the body as a "bank" must be explored and the lost tissue/part replaced with the most similar and closest tissue/part available on the patient (Level 4). However, there is a limit beyond which it is not possible to achieve satisfactory restoration of function/appearance because the missing tissue has some unique characteristics that are not found anywhere else on the body. For instance, if the loss of a thumb can be successfully reconstructed by either using a simple flap, such as an osteocutaneous flap from the forearm, or in a much more functional way by transferring a toe, then the loss of the entire hand is not amendable with autologous tissue due to both its size and unique function. When facing these clinical situations, a microsurgeon is bound to admit defeat and accept the impossibility of using the usual strategy of thinking about the patient's body as a bank to carve out a vascularised free flap that can be moved across, restoring the initial situation. Some have been exploring the area of prefabrication or prelamination of flaps to assemble new and more versatile flaps according to needs, for example, when facing an ear or nose reconstruction, but we are aware that we are far away from perfection in this area. It is evident, therefore, that if a unique body part is needed but is either unavailable or impossible to be custom made, the most logical choice is to adopt the same strategy as that of a transplantation surgeon and consider harvesting the same part/composite tissue as an allograft from a donor (Level 5).

In Table 1, we offer a schematic representation of these five levels, showing their grade of difficulty, provenience and typical application (elective or trauma).

In the following section we present some clinical explanatory examples of the different levels of reconstructive microsurgery, from level 1 to level 5.

Table 1. Levels of reconstructive microsurgery

RECONSTRUCTIVE MICROSURGERY LEVELS			
	TYPE		COMPLEXITY
ORTHOTOPIC REPLANTATION	TRAUMA	OMOGRAFT	++
ETHEROTOPIC REPLANTATION	TRAUMA	OMOGRAFT	+++
COVERAGE FREE FLAP	TRAUMA ELECTIVE	OMOGRAFT	+
FUNCTIONAL FREE FLAP	TRAUMA ELECTIVE	OMOGRAFT	+++
TRANSPLANTATION FREE FLAP	ELECTIVE	ALLOGRAFT	++++

Level 1: Orthotopic Replantation

These procedures are performed in emergency situations; minor or major parts might need to be replanted according to the level of amputation (Figs. 1-3). They can be graded as medium complexity.

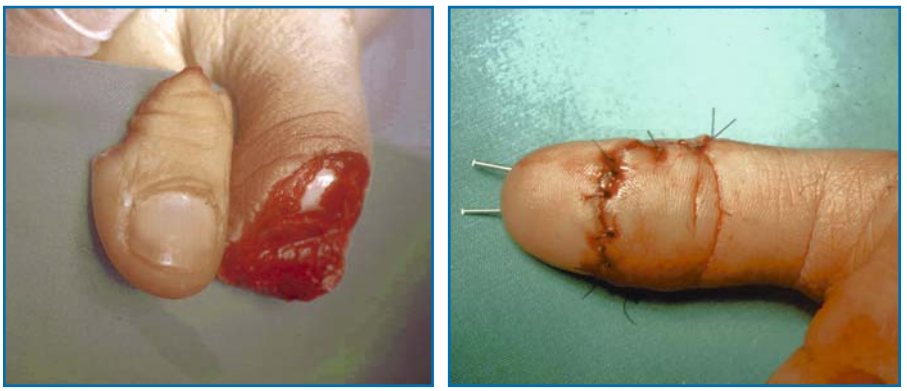

Fig. 1. Orthotopic replantation of a small peripheral part (thumb, distal phalanx)

Fig. 2. Routine orthotopic replantation of two fingers and revascularisation of a third finger

Fig. 3. Orthotopic replantation of a major body part (forearm)

Level 2: Heterotopic Replantation

These operations are carried out in emergency-only conditions, as those in Level 1, but present a higher degree of difficulty/complexity (Figs. 4, 5). Extra planning is necessary to achieve a satisfactory functional result and restore conditions close to those before the trauma.

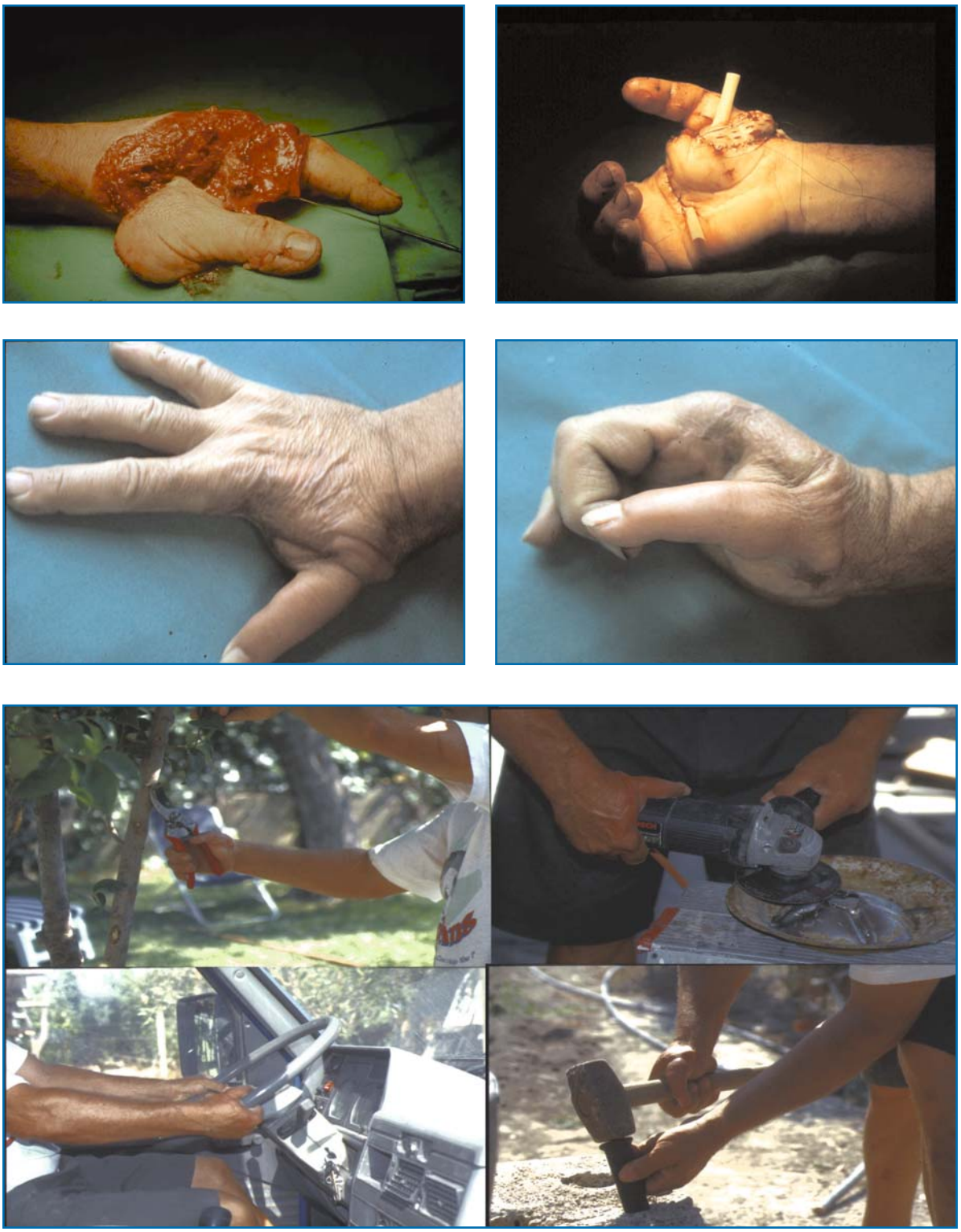

Fig. 4. Heterotopic replantation. The thumb cannot be replanted due to the traumatic avulsion. The index finger is replanted on the thumb position. The result is a functional hand, including pinch. This procedure can be called "replanted pollicisation"