CAMPBELL'S OPERATIVE ORTHOPAEDICS

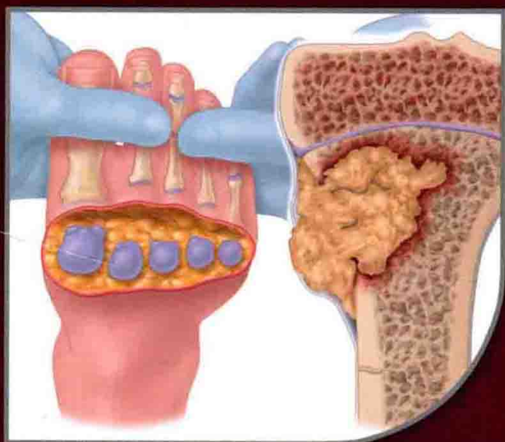
TWELFTH EDITION

英文影印版

坎贝尔骨科手术学

第 12 版

截肢及感染分册



S. Terry Canale • James H. Beaty

天津出版传媒集团

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著作权合同登记号：图字：02-2013-140

图书在版编目（CIP）数据

坎贝尔骨科手术学：第12版. 截肢及感染分册：英文/（美）卡奈尔（Canale, S.T.），（美）贝蒂（Beaty, J.H.）主编. —影印本. —天津：天津科技翻译出版有限公司，2013.6

ISBN 978-7-5433-3249-2

Ⅰ. ①坎… Ⅱ. ①卡… ②贝… Ⅲ. ①骨科学—外科手术—英文 ②截肢—外科手术—英文 ③截肢—感染—英文 Ⅳ. ①R68 ②R687.5

中国版本图书馆CIP数据核字（2013）第130642号

This edition of pages 597 through 786 of Campbell's Operative Orthopaedics (12/E) by S. Terry Canale and James H. Beaty is published by arrangement with Elsevier.
ISBN-13:978-0-323-07243-4
ISBN-10:0-323-07243-7

Elsevier(Singapore) Pte Ltd.
3 Killiney Road, #08-01 Winsland House I, Singapore 239519
Tel:(65)6349-0200 Fax:(65)6733-1817
First Published 2013, 2013年初版

授权单位：Elsevier (Singapore) Pte Ltd.
出 版 人：刘 庆
出　　版：天津科技翻译出版有限公司
地　　址：天津市南开区白堤路244号
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网　　址：www.tsttpc.com
印　　刷：山东鸿杰印务集团有限公司
发　　行：全国新华书店
版本记录：889×1194　16开本　12.5印张　240千字
2013年6月第1版　2013年6月第1次印刷
定价：60.00元

（如发现印装问题，可与出版社调换）

影印版序

《坎贝尔骨科手术学》由世界级专家联袂编撰，自1939年问世以来，这部巨著伴随了一代又一代骨科医生的成长，成为全球骨科医生不可或缺的参考书，是骨科学领域最权威的著作，同样也被我国广大骨科医生奉为经典。

2013年初，Elsevier 出版公司出版了这部骨科学“圣经”的最新版本——第12版，作为一名旧版的老读者，再次切身感受到该书的严谨、科学。新版分4卷，19部分，89章。介绍了骨科手术的基本原理，详细讲述了髋、膝、踝、肩肘关节置换术，以及截肢与感染、骨肿瘤、先天性异常和发育异常、脊柱损伤、运动损伤、成人骨折与脱位、周围神经损伤、手和足踝部损伤的各种手术技术、儿童神经系统疾病及骨折与脱位。此外，还介绍了关节镜及显微外科的先进手术技术和经验。本书的特点是详细地叙述了各种手术的细节，包括手术指征、手术前后处理和并发症防治的原则、各种技巧和注意事项，还配备详细的手术图解，编排合理，非常符合临床骨科医生的学习需要。

新版《坎贝尔骨科手术学》达到了“去粗存精”、“去伪存真”之目的，删除了第11版中一些陈旧的观点和方法，吸取了近年来的最新成果，除保留作为“金标准”的经典技术之外，还介绍了大量新技术、新装备，并强调了微创骨科技术，对当前及今后一段时间的骨科临床和科研具有非常重要的指导作用。新版配图7000余幅，其中很多图片为重新绘制，直观展现骨科手术技术要点。

随着我国骨科界对外交流的日益增加，以及骨科医生英语水平的整体提高，越来越多的骨科医生希望能够尽快读到原汁原味的国外经典之作，恰逢此时，天津科技翻译出版有限公司在第12版《坎贝尔骨科手术学》刚刚推出之际，便立即引进了这部巨著的影印版本，几乎与原版同步出版，让国内读者在第一时间即能零距离地领略到这部经典原著的风采，更直接地分享这些国际骨科权威专家们对骨科手术学的真知灼见！考虑到读者的需求，出版社将影印版设计为两种形式出版。一种是如原版书，做成精装四卷的形式，另一种则按照骨科学的分支，将这套专著做成平装版，分为14个分册，可以让读者各取所需。此外，影印版均采用优质铜版纸印刷，保持了原版书的风貌，其性价比之高在近些年的影印版书中亦不多见。

最后，借此书出版之际，愿全体骨科同仁不断更新知识、锻炼技能，更好地为广大患者解除病痛，为我国的骨科事业的快速、健康发展做出更大的贡献！

中国工程院院士

PREFACE

As with every edition of this text, we have been amazed by the multitude of new techniques, new equipment, and new information generated by our orthopaedic colleagues worldwide. The emphasis on less-invasive surgical techniques for everything from hallux valgus correction to spine surgery to total joint arthroplasty has produced a variety of new approaches and new devices. The use of arthroscopy and endoscopy continues to expand its boundaries. We have attempted to include the latest orthopaedic procedures, while retaining many of the classic techniques that remain the "gold standards."

Some of the changes in this edition that we believe will make it easier to use include the complete redrawing of the thousands of illustrations, the combining of some chapters and rearrangement of others to achieve a more logical flow of information, the addition of several new chapters, and the placement of references published before 2000 on the website only. Full access to the text and to an increased number of surgical videos is available on Expert-Consult.com, which is included with the purchase of the text. This combination of traditional and electronic formats, we believe, will make this edition of *Campbell's Operative Orthopaedics* easily accessible and useable in any situation, making it easier for orthopaedists to ensure the highest quality of patient care.

The true "heroes" of this work are our dedicated authors, who are willing to endure time away from their families and their practices to make sure that their contributions are as up-to-date and informational as possible. The revision process is lengthy and arduous, and we are truly appreciative of the time and effort expended by all of our contributors. As always, the personnel of the Campbell Foundation—Kay Daugherty, Barry Burns, Linda Jones, and Joan Crowson—were essential in getting the ideas and information from 40 authors into a workable form. The progress of the book was marked by the proliferation of paper-stuffed file folders spread across their offices. Managing to transform all of that raw material into readable text and illustrative images is always an amazing accomplishment. Our thanks, too, to the individuals at Elsevier publishing who provided much guidance, encouragement, and assistance: Taylor Ball, Content Development Editor; Dolores Meloni, Executive Content Strategist; Mary Gatsch, Publishing Director; and John Casey, Project Manager.

We are most grateful to our families, especially our wives, Sissie Canale and Terry Beaty, who patiently endured our total immersion in the publication process.

The individuals who often are overlooked, or at least not recognized often enough, are the community of orthopaedic surgeons to whom we are indebted for their expertise and innovation that make a textbook such as ours necessary. As Dr. Campbell noted in the preface to the first edition of this text, "In some of the chapters we have drawn heavily from authoritative articles on special subjects; the author gratefully acknowledges his indebtedness for this material." We are indeed grateful, and honored and humbled, to be the conduit of such remarkable skill and knowledge that help us to make the most current information available to our readers. We hope that this latest edition of *Campbell's Operative Orthopaedics* will prove to be a valuable tool in providing the best of care to orthopaedic patients.

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CONTENTS

PART VI

AMPUTATIONS

14 **General Principles of Amputations** 598
Patrick C. Toy

15 **Amputations of the Foot** 613
David R. Richardson

16 **Amputations of the Lower Extremity** 637
Marc J. Mihalko

17 **Amputations of the Hip and Pelvis** 651
Marc J. Mihalko

18 **Amputations of the Upper Extremity** 659
Kevin B. Cleveland

19 **Amputations of the Hand** 673
James H. Calandruccio

PART VII

INFECTIONS

20 **General Principles of Infection** 706
Kevin B. Cleveland

21 **Osteomyelitis** 725
Gregory D. Dabov

22 **Infectious Arthritis** 749
Anthony A. Mascioli and Ashley L. Park

23 **Tuberculosis and Other Unusual Infections** 773
Marc J. Mihalko

List of Techniques

Amputations of the Foot

15-1 Terminal Syme Amputation, 615
15-2 Amputation at the Base of the Proximal Phalanx, 616
15-3 Metatarsophalangeal Joint Disarticulation, 617
15-4 Metatarsophalangeal Joint Disarticulation, 619
15-5 First or Fifth Ray Amputation (Border Ray Amputation), 619
15-6 Central Ray Amputation, 620
15-7 Transmetatarsal Amputation, 622
15-8 Chopart Amputation, 624
15-9 Syme Amputation, 627
15-10 Two-Stage Syme Amputation (Wyss et al.; Malone et al.; Wagner), 632
15-11 Boyd Amputation, 633

Amputations of the Lower Extremity

16-1 Transtibial Amputation, 638
16-2 Transtibial Amputation Using Long Posterior Skin Flap (Burgess), 640
16-3 Knee Disarticulation (Batch, Spittler, and McFaddin), 642
16-4 Knee Disarticulation (Mazet and Hennessy), 644
16-5 Knee Disarticulation (Kjøble), 645
16-6 Transfemoral (Above-Knee), Amputation of Nonischemic Limbs, 646
16-7 Transfemoral (Above-Knee), Amputation of Nonischemic Limbs (Gottschalk), 646
16-8 Transfemoral (Above-Knee), Amputation for Ischemic Limbs, 648

Amputations of the Hip and Pelvis

17-1 Anatomical Hip Disarticulation (Boyd), 651
17-2 Posterior Flap (Slocum), 653
17-3 Standard Hemipelvectomy, 653
17-4 Anterior Flap Hemipelvectomy, 655
17-5 Conservative Hemipelvectomy, 655

Amputations of the Upper Extremity

18-1 Amputation at the Wrist, 659
18-2 Disarticulation of the Wrist, 660
18-3 Distal Forearm (Distal Transradial) Amputation, 660
18-4 Proximal Third of Forearm (Proximal Transradial) Amputation, 662
18-5 Disarticulation of the Elbow, 662
18-6 Supracondylar Area, 663
18-7 Amputation Proximal to the Supracondylar Area, 664
18-8 Amputation Through the Surgical Neck of the Humerus, 664
18-9 Disarticulation of the Shoulder, 664
18-10 Anterior Approach (Berger), 667
18-11 Posterior Approach (Littlewood), 671

Amputations of the Hand
19-1 Kutler V-Y Triangular Advancement Flap (Kutler; Fisher), 678
19-2 Atasoy V-Y Triangular Advancement Flap (Atasoy et al.), 680
19-3 Bipedicle Dorsal Flaps, 681
19-4 Adipofascial Turnover Flap, 682
19-5 Thenar Flap, 682
19-6 Local Neurovascular Island Flap, 683
19-7 Island Pedicle Flap, 683
19-8 Retrograde Island Pedicle Flap, 684
19-9 Ulnar Hypothenar Flap, 685
19-10 Index Ray Amputation, 685
19-11 Transposing the Index Ray (Peacock), 687
19-12 Advancement Pedicle Flap for Thumb Injuries, 690
19-13 Phalangization of Fifth Metacarpal, 691
19-14 Krukenberg Reconstruction (Krukenberg; Swanson), 692
19-15 Lengthening of Metacarpal and Transfer of Local Flap (Gillies and Millard, Modified), 695
19-16 Osteoplastic Reconstruction and Transfer of Neurovascular Island Graft (Verdan), 696
19-17 Riordan Pollicization (Riordan), 696
19-18 Buck-Gramcko Pollicization (Buck-Gramcko), 698
19-19 Foucher Pollicization, 700

Osteomyelitis
21-1 Drainage of Acute Hematogenous Osteomyelitis, 729
21-2 Sequestrectomy and Curettage for Chronic Osteomyelitis, 734
21-3 Open Bone Grafting (Papineau et al.; Archdeacon and Messerschmitt), 735
21-4 Antibiotic Bead Pouch (Henry, Ostermann, and Seligson), 736
21-5 Intramedullary Antibiotic Cement Nail, 736
21-6 Split-Heel Incision (Gaenslen), 741
21-7 Distal Third of the Femur, 741
21-8 Drainage, 742
21-9 Resection of the Metatarsals, 743
21-10 Partial Calcanectomy, 743
21-11 Resection of the Fibula, 744
21-12 Resection of the Iliac Wing (Badgley), 744

Infectious Arthritis
22-1 Surgical Drainage of the Tarsal Joint, 753
22-2 Anterolateral Drainage of the Ankle, 753
22-3 Posterolateral Drainage of the Ankle, 753
22-4 Anteromedial Drainage of the Ankle, 754
22-5 Posteromedial Drainage of the Ankle, 754
22-6 Arthroscopic Drainage of the Knee, 755
22-7 Anterior Drainage of the Knee, 755
22-8 Posterolateral and Posteromedial Drainage of the Knee (Henderson), 755
22-9 Posteromedial Drainage of the Knee (Klein), 755
22-10 Posteromedial and Posterolateral Drainage of the Knee (Kelikian), 756
22-11 Lateral Aspiration of the Hip, 757
22-12 Anterior Aspiration of the Hip, 758
22-13 Medial Aspiration of the Hip, 758
22-14 Posterior Drainage of the Hip (Ober), 758
22-15 Anterior Drainage of the Hip, 758
22-16 Lateral Drainage of the Hip, 758
22-17 Medial Drainage of the Hip (Ludloff), 759
22-18 Resection of the Hip (Girdlestone), 761
22-19 Anterior Drainage of the Shoulder, 762
22-20 Posterior Drainage of the Shoulder, 763
22-21 Medial Drainage of the Elbow, 763
22-22 Lateral Drainage of the Elbow, 763
22-23 Posterior Drainage of the Elbow, 764
22-24 Lateral Drainage of the Wrist, 764
22-25 Medial Drainage of the Wrist, 765
22-26 Dorsal Drainage of the Wrist, 765
22-27 Osteotomy of the Ankle, 765
22-28 Transverse Supracondylar Osteotomy of the Femur, 765
22-29 V-Osteotomy of the Femur (Thompson), 766
22-30 Supracondylar Cuneiform Osteotomy of the Femur, 766
22-31 Supracondylar Controlled Rotational Osteotomy of the Femur, 766
22-32 Intraarticular Osteotomy, 768
22-33 Reconstruction after Hips Sepsis (Harmon), 769
22-34 Transverse Opening Wedge Osteotomy of the Hip, 770
22-35 Transverse Closing Wedge Osteotomy of the Hip, 771
22-36 Brackett Osteotomy of the Hip (Brackett), 771

Tuberculosis and Other Unusual Infections
23-1 Curettage for Tuberculous Lesions in the Foot, 776
23-2 Excision of Metatarsal, 776
23-3 Excision of Cuneiform Bones, 777
23-4 Excision of Navicular, 777
23-5 Excision of Cuboid, 777
23-6 Excision of Calcaneus, 777
23-7 Excision of Talus, 777
23-8 Partial Synovectomy and Curettage (Wilkinson), 779
23-9 Lesions above Acetabulum, 779
23-10 Lesions of the Femoral Neck, 779
23-11 Lesions of the Trochanteric Area (Ahern), 780
23-12 Excision of the Hip Joint, 780
23-13 Excision of Elbow Joint, 781
23-14 Excision of Wrist Joint, 781

GENERAL PRINCIPLES OF AMPUTATIONS

CHAPTER 14

Patrick C. Toy

INCIDENCE AND INDICATIONS 598
PERIPHERAL VASCULAR DISEASE 599
TRAUMA 599
BURNS 601
FROSTBITE 601
INFECTION 601
TUMORS 602
SURGICAL PRINCIPLES OF AMPUTATIONS 603
DETERMINATION OF AMPUTATION LEVEL 603
TECHNICAL ASPECTS 604
Skin and Muscle Flaps 604
Hemostasis 605
Nerves 605
Bone 605
OPEN AMPUTATIONS 605
POSTOPERATIVE CARE 605
COMPLICATIONS 606
HEMATOMA 606
INFECTION 606
WOUND NECROSIS 607
CONTRACTURES 607
PAIN 608
DERMATOLOGICAL PROBLEMS 608
AMPUTATIONS IN CHILDREN 609

Amputation is the most ancient of surgical procedures. Advancements in surgical technique and prosthetic design historically were stimulated by the aftermath of war. Early surgical amputation was a crude procedure by which a limb was rapidly severed from an unanesthetized patient. The open stump was crushed or dipped in boiling oil to obtain hemostasis. The procedure was associated with a high mortality rate. For patients who survived, the resulting stump was poorly suited for prosthetic fitting.

Hippocrates was the first to use ligatures; this technique was lost during the Dark Ages but was reintroduced in 1529 by Ambroise Paré, a French military surgeon. Paré also introduced the "artery forceps." He was able to reduce the mortality rate significantly while creating a more functional stump. He also designed relatively sophisticated prostheses. Further advances were made possible by Morel's introduction of the tourniquet in 1674 and Lister's introduction of antiseptic technique in 1867. With the use of chloroform and ether for general anesthesia in the late 19th century, surgeons for the first time could fashion reasonably sturdy and functional stumps.

During the 1940s in the United States, veterans began to voice their concerns over the poor performance of their artificial limbs, which prompted Surgeon General of the Army, Norman T. Kirk, to turn to the National Academy of Sciences. This led to the formation of the Advisory Committee on Artificial Limbs, later the Prosthetics Research Board, and finally the Committee on Prosthetics Research and Development.

Today, federally funded prosthetic research continues through university programs. With better understanding of biology and physiology, surgical technique and postoperative rehabilitation have improved. New information regarding biomechanics and materials has greatly improved prosthetic design. Patients with amputations now can enjoy higher levels of activity. Older patients, who previously would have been wheelchair dependent, are now more likely to regain ambulatory ability. Younger patients now have access to specialized prostheses that allow them to resume recreational activities such as running, golfing, skiing, hiking, swimming, and other competitive sports.

Now more than ever it is important that amputations be performed by surgeons who have a complete understanding of amputation surgical principles, postoperative rehabilitation, and prosthetic design. Improved prosthetic design does not compensate for a poorly performed surgical procedure. Amputation should not be viewed as a failure of treatment but rather as the first step toward a patient's return to a more comfortable and productive life. The operative procedure should be planned and performed with the same care and skill used in any other reconstructive procedure.

INCIDENCE AND INDICATIONS

The National Center for Health Statistics estimated that more than 300,000 patients with amputations live in the United States. The number of amputations performed each year is increasing, mainly because of an aging population. More than 90% of amputations performed in the Western world are secondary to peripheral vascular disease. In younger patients, trauma is the leading cause, followed by malignancy.

The only absolute indication for amputation is irreversible ischemia in a diseased or traumatized limb. Amputation also may be necessary to preserve life in patients with uncontrollable infections and may be the best option in some patients with tumors, although advances in orthopaedic oncology now allow limb salvage in most cases. Injury not affecting circulation may result in a limb that it is not as functional as a prosthesis. Similarly, certain congenital anomalies of the lower extremity are best treated with amputation and prosthetic fitting. Each of these indications is discussed in further detail.

PERIPHERAL VASCULAR DISEASE

Peripheral vascular disease with or without diabetes, which most frequently occurs in individuals age 50 to 75, is the most common indication for amputation. The treating physician should keep in mind that if vascular disease has progressed to the point of requiring amputation, it is not limited to the involved extremity. Most patients also have concomitant disease processes in the cerebral vasculature, coronary arteries, and kidneys. In addition to obtaining a vascular surgery consultation to evaluate the diseased limb, appropriate consultation is indicated to evaluate these other systems.

Approximately half of amputations for peripheral vascular disease are performed on patients with diabetes. The most significant predictor of amputation in diabetics is peripheral neuropathy as measured by insensitivity to the Semmes-Weinstein 5.07 monofilament. Other documented risk factors include prior stroke, prior major amputation, decreased transcutaneous oxygen levels, and decreased ankle-brachial blood pressure index. Diabetics must be instructed on the importance of proper foot care and footwear and must examine their feet frequently. Ulcers should be treated aggressively with appropriate pressure relief, orthoses, total-contact casting, wound care, and antibiotics when indicated. Other risk factors, including smoking and poor glucose control, should be minimized.

Before performing an amputation for peripheral vascular disease, a vascular surgery consultation is almost always indicated. Improved techniques currently allow for revascularization of limbs that previously would have been unsalvageable. Revascularization is not without risk, however. Although there is no conclusive evidence in the literature that peripheral bypass surgery compromises wound healing of a future transtibial amputation, our experience seems to indicate otherwise.

If amputation becomes necessary, all effort must be expended to optimize surgical conditions. All medical problems should be treated individually. Infection should be controlled as effectively as possible, and nutrition and immune status should be evaluated with simple screening tests. It has been shown that the risk for wound complications is greatly increased in patients whose serum albumin is less than 3.5 g/dL or whose total lymphocyte count is less than 1500 cells/mL. Perioperative mortality rates for amputation in peripheral vascular disease have been reported to be 30%, and 40% of patients die within 2 years. Critical ischemia develops in the remaining lower extremity in 30% of the remaining patients.

Determining the appropriate level of amputation is discussed later in this chapter. The energy required for walking is inversely proportionate to the length of the remaining limb. In an elderly patient with multiple medical problems, energy reserves may not allow for ambulation if the amputation is at a proximal level. If a patient's cognitive function, balance, strength, and motivation level are sufficient for ambulatory rehabilitation to be a reasonable goal, amputation should be performed at the most distal level that offers a reasonable chance of healing to maximize function. Conversely, a nonambulatory patient with a knee flexion contracture should not undergo a transtibial amputation because a transfemoral amputation or knee disarticulation provides better function and less risk.

TRAUMA

Trauma is the leading indication for amputations in younger patients. Amputations as a result of trauma are more common in men because of vocational and avocational hazards. These patients are often otherwise healthy and productive, and such injuries may have profound effects on their lives. The only absolute indication for primary amputation is an irreparable vascular injury in an ischemic limb. With improvements in prehospital care, acute resuscitation, microvascular techniques, and bone transport techniques, orthopaedic surgeons more often are faced with situations in which a severely traumatized limb can be preserved, although this involves substantial compromises.

Several studies have suggested guidelines to help decide which limbs are salvageable. Most of these studies have concentrated on severe injuries of the lower extremity. Most authors would agree that type III-C open tibial fractures, which include complete disruption of the tibial nerve or a crush injury with warm ischemia time of more than 6 hours, are an absolute indication for amputation. Relative indications for primary amputation include serious associated injuries, severe ipsilateral foot injuries, and anticipated protracted course to obtain soft tissue coverage and tibial reconstruction. Although these relative indications are subject to various interpretations, they serve as reasonable guidelines.

Other authors have attempted to remove subjectivity from the decision-making process. To predict which limbs will be salvageable, available scoring systems include the predictive salvage index, the limb injury score, the limb salvage index, the mangled extremity syndrome index, and the mangled extremity severity score. Of these, we have found the mangled extremity severity score to be most useful (Table 14-1). This system, which is easy to apply, grades the injury on the basis of the energy that caused the injury, limb ischemia, shock, and the patient's age. The system was subjected to retrospective and prospective studies, with a score of 6 or less consistent with a salvageable limb. With a score of 7 or greater, amputation was the eventual result. Although we do not strictly follow these guidelines in all patients, we do calculate and document a mangled extremity severity score in the chart whenever we are considering primary amputation versus a complicated limb salvage.

No scoring system can replace experience and good clinical judgment. Amputation of an injured extremity might be necessary to preserve life. Attempts to salvage a severely injured limb may lead to metabolic overload and secondary organ failure. This is more common in patients with multiple injuries and in the elderly. It has been suggested that an injury severity score of greater than 50 is a contraindication to heroic attempts at limb salvage. Concomitant injuries and comorbid medical conditions must be considered before heading down a long road of multiple operations to save a limb.

TABLE 14-1 Mangled Extremity Severity Score

TYPE	CHARACTERISTICS	INJURIES	POINTS
1	Low energy	Stab wounds, simple closed fractures, small-caliber gunshot wounds	1
2	Medium energy	Open or multiple-level fractures, dislocations, moderate crush injuries	2
3	High energy	Shotgun blast (close range), high-velocity gunshot wounds	3
4	Massive crush	Logging, railroad, oil rig accidents	4
SHOCK GROUP			
1	Normotensive hemodynamics	Stable blood pressure in field and in operating room	0
2	Transiently hypotensive	Unstable blood pressure in field but responsive to intravenous fluids	1
3	Prolonged hypotension	Systolic blood pressure < 90 mm Hg in field and responsive to intravenous fluid only in operating room	2
ISCHEMIA GROUP			
1	None	Pulsatile limb without signs of ischemia	0*
2	Mild	Diminished pulses without signs of ischemia	1*
3	Moderate	No pulse on Doppler imaging, sluggish capillary refill, paresthesia, diminished motor activity	2*
4	Advanced	Pulseless, cool, paralyzed, and numb without capillary refill	3*
AGE GROUP			
1	< 30 y		0
2	>30-<50 y		1
3	>50 y		2

*Points × 2 if ischemic time exceeds 6 hours.

From Helfet DL, Howey T, Sanders R, et al: Limb salvage versus amputation: preliminary results of the mangled extremity severity score, *Clin Orthop Relat Res* 256:80, 1990.

After determining that a limb *can* be saved, the surgeon must decide whether it *should* be saved, and this decision must be made in concert with the patient. The surgeon must educate the patient regarding the tradeoffs involved with a protracted treatment course of limb salvage versus immediate amputation and prosthetic fitting. On entering the hospital, most patients are concerned only with saving the limb; they must be made to understand that this often comes at a great cost. They may have to face multiple operations to obtain bony union and soft tissue coverage and multiple operations on other areas to obtain donor tissue. External fixation may be necessary for several years, and complications, including infection, nonunion, or loss of a muscle flap, may occur. Chronic pain and drug addiction also are common problems of limb salvage because patients endure multiple hospital admissions and surgery, isolation from their family and friends, and unemployment. In the end, despite heroic efforts, the limb ultimately could require amputation, or a "successfully" salvaged limb may be chronically painful or functionless.

Patients also need to understand that the advances made in limb salvage surgery have been paralleled by advances made in amputation surgery and prosthetic design. Early amputation and prosthetic fitting are associated with decreased morbidity, fewer operations, a shorter hospital course, decreased hospital costs, shorter rehabilitation, and earlier return to work. The treatment course and outcome are more predictable. Modern prosthetics often provide better function than many "successfully" salvaged limbs. A young healthy patient with a transtibial prosthesis often is able to resume all previous activities with few restrictions. In long-term studies, patients who have undergone amputation and prosthetic fitting are more likely to remain working and are far less likely to consider themselves to be "severely disabled" than patients who have endured an extensive limb salvage.

Several recent comparisons of limb reconstruction and limb amputation have come to differing conclusions, with one large study of 545 patients projecting lifetime health care costs to be three times higher for patients with amputations than for those with reconstruction. A meta-analysis, on the other hand, concluded that length of rehabilitation and total costs are higher for patients who have undergone limb salvage procedures. Reports of functional results have been equally varied, with one study reporting a 64% return-to-work rate after limb salvage compared with 73% after amputation and another study reporting that long-term functional outcomes were equivalent between limb salvage and primary amputation.

The worst-case scenario occurs when a limb must be amputated after the patient has endured multiple operations of an unsuccessful salvage or after years of pain following a "successful" salvage. After realizing the function that is possible with a prosthesis, many patients ask why the amputation was not performed initially. It is important to present all information from the very beginning so that the patient is able to make educated decisions regarding which course to follow. The physician cannot understand the importance each patient places on cosmesis, function, or body image without specifically asking these questions. Other important issues include the patient's ability to handle uncertainty, deal with prolonged immobilization, accept social isolation, and bear the financial burden. Without discussing all these issues, a physician would not be able to help patients make the "correct" decisions. The "correct" decisions are based on the patient as a whole, not solely on the extent of the limb injury.

When an amputation is performed in the setting of acute trauma, the surgeon must follow all the standard principles of wound management. Contaminated tissue must undergo débridement and irrigation followed by open wound management. Although all devitalized tissue must be removed, any questionable areas should be retained and reevaluated at a repeat débridement in 24 to 48 hours. Functional stump length should be maintained whenever possible; this may require using nonstandard flaps or free muscle flaps for closure. Vascularized or nonvascularized tissue may be harvested from the amputated part to aid in this endeavor. If adequate length cannot be maintained acutely, the stump may be revised at a later date using tissue expanders and the Ilizarov technique for bone lengthening.

BURNS

Thermal or electrical injury to an extremity may necessitate amputation. The full extent of tissue damage may not be apparent at initial presentation, especially with electrical injury. Treatment involves early débridement of devitalized tissue, fasciotomies when indicated, and aggressive wound care, including repeat débridements in the operating room. Compared with early amputation, delayed amputation of an unsalvageable limb has been associated with increased risk of local infection, systemic infection, myoglobin-induced renal failure, and death. In addition, length of hospital stay and cost are greatly increased with delayed amputation. Performing inadequate débridements with the unrealistic hope of saving a limb may put the patient in undue danger. Débridements must be aggressive and must include amputation when necessary.

FROSTBITE

Frostbite denotes the actual freezing of tissue in the extremities, with or without central hypothermia. Historically, frostbite was most prevalent in wartime; however, anyone exposed to subfreezing temperatures is at risk. This is a common problem for high-altitude climbers, skiers, and hunters. Also at risk are homeless, alcoholic, and schizophrenic individuals.

When heat loss exceeds the body's ability to maintain homeostasis, blood flow to the extremities is decreased to maintain central body temperature. The problem is exacerbated by exposure to wind or water. Actual tissue injury occurs through two mechanisms: (1) direct tissue injury through the formation of ice crystals in the extracellular fluid and (2) ischemic injury resulting from damage to vascular endothelium, clot formation, and increased sympathetic tone.

The first step in treatment is restoration of core body temperature. Treatment of the affected extremity begins with rapid rewarming in a water bath at 40°C to 44°C. This requires parenteral pain management and sedation. After initial rewarming, if digital blood flow is still not apparent, treatment with tissue plasminogen activator or regional sympathetic blockade may be indicated. Tetanus prophylaxis is mandatory; however, prophylactic systemic antibiotics are controversial. Blebs should be left intact. Closed blebs should be treated with aloe vera. Silver sulfadiazine (Silvadene) should be applied regularly to open blebs. Low doses of aspirin or ibuprofen also should be instituted. Oral anti-inflammatory medication and topical aloe vera help to stop progressive dermal ischemia mediated by vasoconstricting metabolites of arachidonic acid in frostbite wounds. Physical therapy should be started early to maintain range of motion.

In stark contrast to traumatic, thermal, or electrical injury, amputation for frostbite routinely should be delayed 2 to 6 months. Clear demarcation of viable tissue may take this long. Even after demarcation appears to be complete on the surface, deep tissues still may be recovering. Despite the presence of mummified tissue, infection is rare if local wound management is maintained. Triple-phase technetium bone scan has helped to delineate deep tissue viability. Performing surgery prematurely often results in greater tissue loss and increased risk of infection. An exception to this rule is the removal of a circumferentially constricting eschar.

INFECTION

Amputation may be necessary for acute or chronic infection that is unresponsive to antibiotics and surgical débridement. Open amputation is indicated in this setting and may be performed using one of two methods. A guillotine amputation may be performed with later revision to a more proximal level after the infection is under control. Alternatively, an open amputation may be performed at the definitive level by initially inverting the flaps and packing the wound open with secondary closure at 10 to 14 days.

Partial foot amputation with primary closure has been described for patients with active infection; the wound is closed loosely over a catheter through which an antibiotic irrigant is infused. The constant infusion is continued for 5 days. The wound must be closed loosely enough to allow the fluid to escape into the dressings. The dressings must be changed frequently until the catheter is removed on postoperative day 5. This method may allow for primary wound healing, while avoiding a protracted course of wound healing by secondary intention.

In the acute setting, the most worrisome infections are those produced by gas-forming organisms. Typically associated with battlefield injuries, gas-forming infections also may result from farm injuries, motor vehicle accidents, or civilian

TABLE 14-2 Differential Diagnosis of Infection with Gas-Forming Organisms

FACTOR	ANAEROBIC CELLULITIS	CLOSTRIDIAL MYONECROSIS	STREPTOCOCCAL MYONECROSIS
Incubation	>3 d	<3 d	3-4 d
Onset	Gradual	Acute	Subacute
Toxemia	Slight	Severe	Severe (late)
Pain	Absent	Severe	Variable
Swelling	Slight	Severe	Severe
Skin	Little change	Tense, white	Tense, copper colored
Exudate	Slight	Serous hemorrhagic	Seropurulent
Gas	Abundant	Rarely abundant	Slight
Smell	Foul	Variable, "mousy"	Slight
Muscle involvement	No change	Severe	Moderate

From DeHaven KE, Evarts CM: The continuing problem of gas gangrene: a review and report of illustrative cases, *J Trauma* 11:983, 1971.

gunshot wounds. Any contaminated wound that is closed without appropriate débridement is at high risk for the development of gas gangrene.

Three distinct gas-forming infections must be differentiated (Table 14-2). The first is clostridial myonecrosis, which typically develops within 24 hours of closure of a deep contaminated wound. The patient has an acute onset of pain, swelling, and toxemia, often associated with a mental awareness of impending death. The wound develops a bronze discoloration with a serosanguineous exudate and a musty odor. Gram stain of the exudates shows gram-positive rods occasionally accompanied by other flora. Treatment consists of immediate radical débridement of involved tissue, high doses of intravenous penicillin (clindamycin may be used if the patient is allergic to penicillin), and hyperbaric oxygen. Emergency open amputation one joint above the affected compartments often is needed as a lifesaving measure but may be avoided if treatment is initiated early.

Streptococcal myonecrosis usually develops over 3 to 4 days. The onset is not as rapid, and patients do not appear as sick as patients with clostridial infections. Swelling may be severe, but the pain typically is not as severe as that experienced in clostridial myonecrosis. Abundant seropurulent discharge may be seen with only small amounts of gas formation. Debridement of involved muscle compartments, open wound management, and penicillin treatment usually allow preservation of the limb.

The third entity that must be distinguished is anaerobic cellulitis or necrotizing fasciitis. Onset usually occurs several days after closure of a contaminated wound. Subcutaneous emphysema may spread rapidly, although pain, swelling, and toxemia usually remain minimal. Gas production may be abundant with a foul smell, but muscle compartments are not involved. Causative organisms include clostridia, anaerobic streptococci, *Bacteroides,* and gram-negative rods. Treatment includes débridement and broad-spectrum antibiotics. Amputation rarely is indicated.

Indications for amputation of a chronically infected limb must be defined on an individual basis. The systemic effects of a refractory infection may justify amputation. Disability from a nonhealing trophic ulcer, chronic osteomyelitis, or infected nonunion may reach a point at which the patient is better served by an amputation and prosthetic fitting. Rarely, a chronic draining sinus is the site of development of a squamous cell carcinoma, which necessitates amputation.

TUMORS

Advances in diagnostic imaging, chemotherapy, radiation therapy, and surgical technique for reconstruction now make limb salvage a reasonable option for most patients with bone or soft tissue sarcomas. Four issues must be considered when contemplating limb salvage instead of amputation:

1. Would survival be affected by the treatment choice?
2. How do short-term and long-term morbidity compare?
3. How would the function of a salvaged limb compare with that of a prosthesis?
4. Are there any psychosocial consequences?

Several studies have discussed the first question with regard to osteosarcoma. With the use of multimodal treatment, including surgery and chemotherapy, long-term survival for osteosarcoma patients has improved from approximately 20% to approximately 70% in most series. For osteosarcoma of the distal femur, the rate of local recurrence after wide resection and limb salvage is 5% to 10%, which is equivalent to the local recurrence rate after a transfemoral amputation for osteosarcoma. Although the rate of local recurrence of a tumor after hip disarticulation is extremely low, no study has shown a survival advantage for this technique. In general, provided that wide surgical margins are obtained, no study has proved a survival advantage of one technique over the other.

Amputation for malignancy may be technically demanding, often requiring nonstandard flaps, bone graft, or prosthetic augmentation to obtain a more functional residual limb (Fig. 14-1). Limb salvage is associated with greater perioperative morbidity, however, compared with amputation. Limb salvage involves a more extensive surgical procedure and is associated with greater risk of infection, wound dehiscence, flap necrosis, blood loss, and deep venous thrombosis. Long-term complications vary depending on the type of reconstruction. These include periprosthetic fractures, prosthetic loosening or dislocation, nonunion of the graft-host junction, allograft fracture, leg-length discrepancy, and late infection. A patient with a salvaged limb is more likely to need multiple

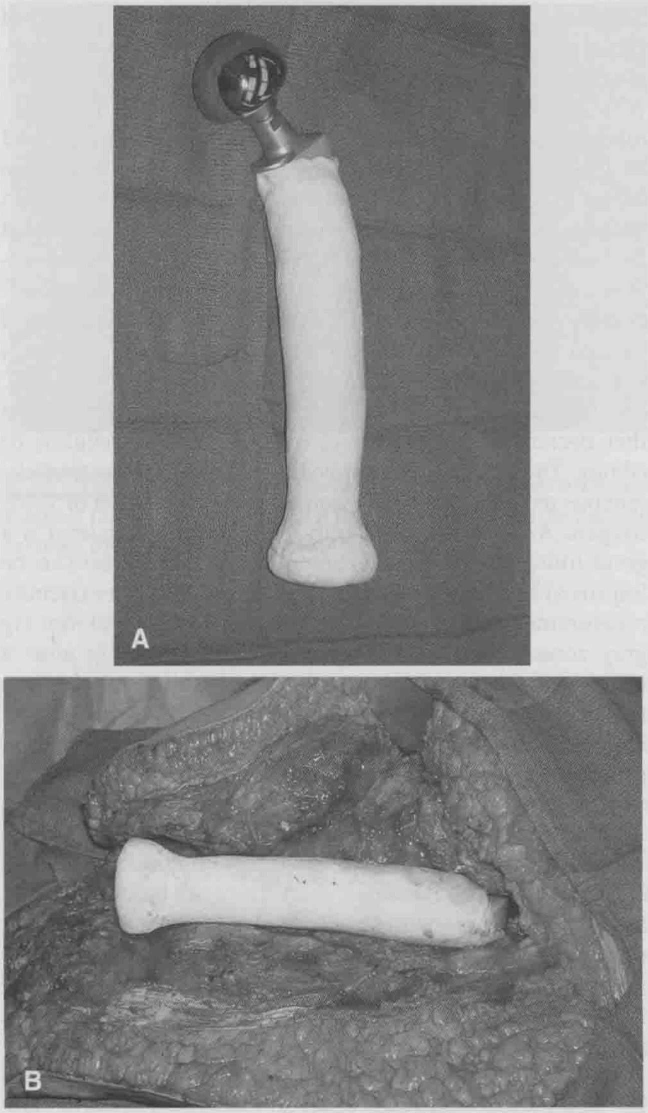

FIGURE 14-1 Hip disarticulation secondary to osteosarcoma. A, Proximal femoral replacement is constructed using hip hemiarthroplasty component and bone cement. B, Anterior and posterior flaps are repaired over prosthesis. Patient is able to function as transfemoral amputee.

subsequent operations for treatment of complications. After initial successful limb salvage surgery, one third of long-term survivors ultimately may require an amputation.

With regard to function, the location of the tumor is the most important factor. Resection of an upper extremity lesion with limb salvage, even with sacrifice of a major nerve, generally provides better function than amputation and subsequent prosthetic fitting. Similarly, resection of a proximal femoral or pelvic lesion with local reconstruction generally provides better function than hip disarticulation or hemipelvectomy. Sarcomas around the ankle and foot frequently are treated with amputation followed by prosthetic fitting. Treatment for sarcomas around the knee must be individualized.

Most patients with osteosarcoma around the knee are treated with one of three surgical procedures—wide resection with prosthetic knee replacement, wide resection with allograft arthrodesis, or a transfemoral amputation. In one study of osteosarcoma patients, patients who had undergone resection and prosthetic knee replacement showed higher self-selected walking velocities and a more efficient gait with regard to oxygen consumption than patients with transfemoral amputations. Individuals with a transfemoral amputation functioned at more than 50% of their maximal aerobic capacity at free walking speeds, requiring anaerobic mechanisms to sustain muscle metabolism, which results in decreased endurance. The problem in many of these patients is compounded by decreased cardiac function from doxorubicin-induced cardiomyopathy.

In a comparison of the long-term function of amputation, arthrodesis, or arthroplasty for the treatment of tumors around the knee, patients with an amputation had difficulty walking on steep, rough, or slippery surfaces but were very active and were the least worried about damaging the affected limb. Patients with an arthrodesis performed the most demanding physical work and recreational activities, but they had difficulty with sitting, especially in the back seat of cars, theaters, or sports arenas. Patients who had arthroplasty generally led more sedentary lives and were more protective of the limb, but they had little difficulty with activities of daily living. These patients also were the least self-conscious about the limb.

No study has shown a significant difference between amputation and limb salvage with regard to psychological outcome or quality of life in long-term sarcoma survivors. The decision of limb salvage versus amputation involves more than the question of whether the lesion can be resected with wide margins. The patient ultimately must make the final decision in light of long-term goals and lifestyle decisions.

Rarely, amputation may be indicated as a palliative measure for a patient with metastatic disease and pain that has been refractory to standard surgical treatment, radiation, chemotherapy, and narcotic pain management. Amputation may be indicated for treatment of a recurrent pathological fracture in which stabilization is impossible. It also may be indicated if the malignancy has caused massive necrosis, fungation, infection, or vascular compromise. Although cure is not the goal, amputation may dramatically improve the functional status and pain relief for the remaining months in some patients. The surgeon must remember, however, that survival is not always predictable. One such "palliative" hemipelvectomy was performed at this institution on a patient who subsequently lived comfortably for an additional 20 years.

SURGICAL PRINCIPLES OF AMPUTATIONS

DETERMINATION OF AMPUTATION LEVEL

Determining the appropriate level of amputation requires an understanding of the tradeoffs between increased function with a more distal level of amputation and a decreased complication rate with a more proximal level of amputation. The patient's overall well-being, general medical condition, and rehabilitation all are important factors.

A vascular surgery consultation is almost always appropriate. Even if revascularization would not allow for salvage of the entire limb, it may allow for healing of a partial foot or ankle amputation instead of a transtibial amputation. As previously stated, however, peripheral bypass surgery may compromise wound healing of a future transtibial amputation.

Simple screening tests for nutritional status and immunocompetence should be performed. Medical illness, infection, and major operations all induce a hypermetabolic state. Multiple studies have confirmed that malnourished or immunocompromised patients have markedly increased rates of perioperative complications.

Waters et al. studied the energy cost of walking for patients with amputations at the transfemoral, transtibial, and Syme levels secondary to trauma or chronic limb ischemia. Compared with controls without amputations, the self-selected walking velocity for vascular amputees was 66% at the Syme level, 59% at the transtibial level, and 44% at the transfemoral level. For traumatic amputees, generally younger patients, the rates were 87% at the transtibial level and 63% at the transfemoral level. At self-selected walking velocities, the slower rates for amputees seem to be a compensatory mechanism to conserve energy per unit time. With the exception of transfemoral amputations secondary to vascular insufficiency, all patients tended to ambulate at similar percentages of their maximal aerobic capacity compared with age-matched controls. Patients tended to decrease their velocities to keep their relative energy costs per minute within normal limits. Patients with transfemoral amputations secondary to vascular insufficiency were unable to accomplish this, however, often exceeding 50% of their maximal aerobic capacity even for minimal ambulation. In this state, as already mentioned, anaerobic mechanisms are summoned to sustain muscle function, and endurance is greatly compromised. As a result, fewer vascular transfemoral amputees regain functional ambulatory ability. It becomes apparent that amputation should be performed at the most distal level possible if ambulation is the chief concern.

If a patient has no ambulatory potential, wound healing with decreased perioperative morbidity should be the chief concern. A transtibial amputation in this setting is not a reasonable option because of the increased risk of wound problems and increased skin problems from knee flexion contractures. A knee disarticulation often provides the best function for these patients. Compared with transfemoral amputation, knee disarticulation provides a longer lever arm with balanced musculature to help with bed mobility and transfers. In addition, muscles are not divided and do not atrophy and contract over the femur as they often do after transfemoral amputation. Finally, better sitting stability and comfort are provided with a through-knee amputation.

Determining the most distal level for amputation with a reasonable chance of healing can be challenging. Preoperatively, clinical assessment of skin color, hair growth, and skin temperature provides valuable initial information. Preoperative arteriograms, although already obtained for vascular surgery consultation, are of little help in determining potential for wound healing. Segmental systolic blood pressures likewise offer little useful information because they are often falsely elevated owing to the noncompliant walls of arteriosclerotic vessels. Measurements of skin perfusion pressures may be of some benefit, however. Some authors have recommended thermography or laser Doppler flowmetry as methods to test skin flap perfusion. Others recommend determining the tissue uptake of intravenously injected fluorescein or the tissue clearance of intradermally injected xenon-133. We have found transcutaneous oxygen measurements to be most beneficial.

Transcutaneous oxygen measurements can be determined at multiple sites along the limb. The test is performed by inserting a probe that is heated to 45°C for 10 minutes before oxygen tension is measured. This allows for a maximum vasodilatory response and a more accurate determination of perfusion potential. Various studies have recommended different cutoff levels, ranging from 20 to 40 mm Hg, for "good" healing potential. There is, however, no absolute cutoff because some studies have shown healing rates of 50% even when the transcutaneous oxygen level is less than 10 mm Hg. The measurement can be falsely decreased in circumstances that decrease the diffusion of oxygen, such as cellulitis or edema. The test can be improved by comparing the transcutaneous oxygen level before and after the inhalation of 100% oxygen. An increase of 10 mm Hg at a particular level is a good indicator for healing potential. Accuracy also can be improved by comparing supine and elevation of the extremity measurements in patients who fall into the 20 to 40 mm Hg gray zone. A decrease of greater than 15 mm Hg after 3 minutes of elevation of the involved limb is a poor prognostic indicator for healing. This information must be used in light of other patient variables, including age, concomitant medical problems, and ambulatory potential.

TECHNICAL ASPECTS

Meticulous attention to detail and gentle handling of soft tissues are important for creating a well-healed and highly functional amputation stump. The tissues often are poorly vascularized or traumatized, and the risk for complications is high.

■ SKIN AND MUSCLE FLAPS

Flaps should be kept thick. Unnecessary dissection should be avoided to prevent further devascularization of already compromised tissues. Covering the end of the stump with a sturdy soft tissue envelope is crucial. Past studies have determined the best type of flaps for each level of amputation, but atypical flaps are always preferable to amputation at a more proximal level. With modern total-contact prosthetic sockets, the location of the scar rarely is important, but the scar should not be adherent to the underlying bone. An adherent scar makes prosthetic fitting extremely difficult, and this type of scar often breaks down after prolonged prosthetic use. Redundant soft tissues or large "dog ears" also create problems in prosthetic fitting and may prevent maximal function of an otherwise well-constructed stump.

Muscles usually are divided at least 5 cm distal to the intended bone resection. They may be stabilized by myodesis (suturing muscle or tendon to bone) or by myoplasty (suturing muscle to periosteum or to fascia of opposing musculature). Jaegers et al. showed that transected muscles atrophy 40% to 60% in 2 years if they are not securely fixed. If possible, myodesis should be performed to provide a stronger insertion, help maximize strength, and minimize atrophy (Fig. 14-2). Myodesed muscles continue to counterbalance their antagonists, preventing contractures and maximizing residual limb function. Myodesis may be

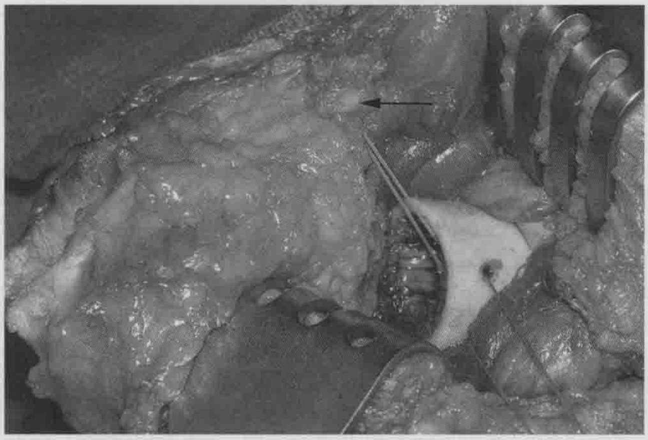

FIGURE 14-2 Myodesis in transfemoral amputation. Adductor magnus tendon *(arrow)* is pulled into cut end of distal femur and secured through drill hole in lateral cortex.

contraindicated, however, in severe ischemia because of the increased risk of wound breakdown.

HEMOSTASIS

Except in severely ischemic limbs, the use of a tourniquet is highly desirable and makes the amputation easier. The limb may be exsanguinated by wrapping it with an Esmarch bandage before the tourniquet is inflated. In amputations for infections or malignancy, however, expressing blood from the limbs in this manner is inadvisable. In such instances, inflation of the tourniquet should be preceded by elevation of the limb for 5 minutes.

Major blood vessels should be isolated and individually ligated. Larger vessels should be doubly ligated. The tourniquet should be deflated before closure, and meticulous hemostasis should be obtained. A drain should be used in most cases for 48 to 72 hours.

NERVES

A neuroma always forms after a nerve has been divided. A neuroma becomes painful if it forms in a position where it would be subjected to repeated trauma. Special techniques have been tried in the hopes of preventing the formation of painful neuromas. These include end-loop anastomosis, perineural closure, Silastic capping, sealing the epineurial tube with butyl-cyanoacrylate, ligation, cauterization, and methods to bury the nerve ends in bone or muscle. Most surgeons currently agree that nerves should be isolated, gently pulled distally into the wound, and divided cleanly with a sharp knife so that the cut end retracts well proximal to the level of bone resection. Strong tension on the nerve should be avoided during this maneuver; otherwise, the amputation stump may be painful even after the wound has healed. Crushing also should be avoided. Large nerves, such as the sciatic nerve, often contain relatively large arteries and should be ligated.

BONE

Excessive periosteal stripping is contraindicated and may result in the formation of ring sequestra or bony overgrowth. Bony prominences that would not be well padded by soft tissue always should be resected, and the remaining bone should be rasped to form a smooth contour. This is especially important in locations such as the anterior aspect of the tibia, lateral aspect of the femur, and radial styloid.

OPEN AMPUTATIONS

An open amputation is one in which the skin is not closed over the end of the stump. The operation is the first of at least two operations required to construct a satisfactory stump. It always must be followed by secondary closure, reamputation, revision, or plastic repair. The purpose of this type of amputation is to prevent or eliminate infection so that final closure of the stump may be done without breakdown of the wound. Open amputations are indicated in infections and in severe traumatic wounds with extensive destruction of tissue and gross contamination by foreign material. Appropriate antibiotics are given until the stump is finally healed.

Previous editions of this book have described the techniques for open amputations with inverted skin flaps and circular open amputations with postoperative skin traction. More recently, in the setting of tissue contamination or severe trauma at the amputation site, we have employed the technique of vacuum-assisted closure. A wound vacuum-assisted closure is applied to the open stump immediately after the initial débridement. Subsequent débridements are scheduled at 48-hour intervals. The vacuum-assisted closure is reapplied after each débridement until the wound is ready for closure.

POSTOPERATIVE CARE

Postoperative care of amputations often requires a multidisciplinary team approach. In addition to the surgeon, this team may include a physical medicine specialist, a physical therapist, an occupational therapist, a psychologist, and a social worker. An internist often is required to help manage postoperative medical problems. All of the same precautions are followed as for any major orthopaedic surgery, including perioperative antibiotics, deep venous thrombosis prophylaxis, and pulmonary hygiene. Pain management includes the brief use of intravenous narcotics followed by oral pain medicine that is tapered as soon as tolerated. Several studies have noted decreased narcotic usage with improved pain management through the use of continuous postoperative perineural infusional anesthesia for several days.

Treatment of the stump from the time the amputation is completed until the definitive prosthesis is fitted is crucial if a strong and functional amputation stump capable of maximum prosthetic use is to be obtained. Since the mid-1970s, there has been a gradual shift from the use of "conventional" soft dressings to the use of rigid dressings, especially in centers performing significant numbers of amputations. The rigid dressing consists of a plaster of Paris cast that is applied to the stump at the conclusion of surgery. Early weight bearing is not an essential part of the postoperative management program. If weight-bearing ambulation is not planned in the immediate postoperative period, the rigid dressing may be applied by the surgeon, observing standard cast application precautions, including appropriate padding of all bony