# Evidence-Based Strategies to Reduce Postoperative Complications in Plastic Surgery

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**Summary:** Reconstructive plastic surgery is vital in assisting patients with reintegration into society after events such as tumor extirpation, trauma, or infection have left them with a deficit of normal tissue. Apart from performing a technically sound operation, the plastic surgeon must stack the odds in the favor of the patient by optimizing them before and after surgery. The surgeon must look beyond the wound, at the entire patient, and apply fundamental principles of patient optimization. This article reviews the evidence behind the principles of patient optimization that are commonly used in reconstructive surgery patients. (*Plast. Reconstr. Surg.* 137: 351, 2016.)

Reconstructive surgery patients, especially those undergoing abdominal wall reconstruction, may have comorbidities that place them at high risk for complications. Thorough preoperative and postoperative optimization of those patients is essential. In this article, we present evidence-based principles for patient optimization in reconstructive surgery, with a focus on patients undergoing abdominal wall reconstruction, who are at especially high risk for complications. Those principles include good communication, appropriate anesthesia, infection control, nutritional optimization, smoking cessation, glucose control, normothermia, sound surgical technique, pain control, topical wound treatment, pulmonary toilet, thromboprophylaxis, and appropriate drain care.

## PATIENT OPTIMIZATION

### Surgeon-Patient Communication

Patient optimization begins at the initial surgical consultation. Before initiating elective surgery, the surgeon must first establish mutual trust and rapport through good communication skills, and set realistic expectations for the upcoming operation. Indeed, the rapport between a surgeon and a patient is one of the main determinants of patient satisfaction after surgery. In a multicenter prospective study of 571 patients undergoing breast reconstruction, Ho et al. found that the top two determinants of patient satisfaction were adequate preoperative information by the surgeon, and satisfaction with the surgeon.[1] Studies have shown that sitting down during a consultation,[2] avoiding the appearance of being hurried, and listening to the patient's questions and concerns lead to patients rating their interaction with the surgeon as positive and overestimating the time that the surgeon actually spent with them. Physicians who educate patients on what to expect, use humor, and encourage patients to ask questions are less likely to encounter medical malpractice claims than physicians who do not.[3] Underpromising and overdelivering is a time-tested method to set patient expectations and maximize satisfaction with surgery.

### Anesthesia Considerations

The choice of whether to perform an operation at a hospital or an outpatient surgery center is an important one. Surgery length of greater than 4 hours and American Society of Anesthesiologists class 3 or greater are predictors of increased complications and readmission,[4–6] and those cases may be better suited for the hospital setting. The choice of general anesthesia versus

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monitored anesthesia care is often dependent on length of surgery, patient preference, comorbidities, and anesthesiology consultation. However, monitored anesthesia care and local anesthesia are being used more commonly, as they decrease postoperative hospital stays, nausea, vomiting, deep venous thrombosis, and operative costs.[7,8] Despite these potential advantages, selection of anesthesia must involve sound clinical judgment and should incorporate the American Society of Plastic Surgeons Task Force Guidelines for Safety in Office-Based Surgery.[9] In addition, normothermia has been shown to reduce surgical-site infection.[10,11] Hypothermia causes impaired platelet function, increased blood loss and transfusion requirements, prolonged hospitalization,[12] and increased cardiac events in patients with coronary artery disease.[13] A Cochrane review of 24 studies found that using warm intravenous fluids helped prevent hypothermia better than room-temperature fluids.[14] Recent studies, however, have found no association between mild intraoperative hypothermia and wound healing complications.[15]

**Infection Control**

Surgical-site infection is a dangerous complication, and can actually undo the surgeon's work. In abdominal wall reconstruction, surgical-site infection is associated with a greater than 80 percent risk of hernia recurrence. Even basic incisional hernia repairs are at high risk for surgical-site infection. In an analysis of 995 clean operations, Houck et al. found that hernias had a 16 percent rate of surgical-site infection, compared to 1.5 percent in other clean surgical procedures.[16] Furthermore, hernias with a history of infection had a 41 percent rate of surgical-site infection, compared with 12 percent in those with no history of infection.

Surgical-site infection may be decreased with appropriate skin preparation and perioperative antibiotics. In a study comparing 10% povidone-iodine (Betadine; Purdue Products, Stamford, Conn.), 2% chlorhexidine/isopropyl alcohol (ChloraPrep; CareFusion Corp., San Diego, Calif.), and iodine povacrylex/isopropyl alcohol (DuraPrep; 3M, St. Paul, Minn.) in 3209 operations, DuraPrep was found to have the lowest rate of surgical-site infection.[17] Because DuraPrep dries as a film of disinfectant, it may resist removal by fluids, thus providing a prolonged protective barrier. Another randomized, multicenter trial comparing chlorhexidine-alcohol to povidone-iodine found lower rates of surgical-site infection in the chlorhexidine group (9.5 percent versus 16.1 percent).[18] The superiority of chlorhexidine may be explained by the additional presence of alcohol in it. Regardless of which surgical preparation is chosen, it is imperative that proper application technique be used and that sufficient time be allowed for drying.

Current Surgical Care Improvement Project guidelines recommend antibiotic administration 1 hour or less before incision.[19] Despite these recommendations, there is continued debate over the efficacy of perioperative antibiotics, particularly in clean, non–implant-based surgery. A meta-analysis of 21 studies examining a broad range of surgical procedures showed that antibiotic prophylaxis was effective at decreasing surgical-site infection.[19] For elective abdominal wall reconstruction, the evidence for perioperative antibiotics is mixed, with some studies showing decreased surgical-site infection with antibiotic prophylaxis,[20] and others not.[21,22]

When given, preoperative antibiotics must be timed appropriately. Most antibiotics have maximal efficacy when administered 30 to 59 minutes before incision.[23] Vancomycin, which has a long infusion time, is typically administered 2 hours before incision,[24] although some studies have found it to be most effective when administered 30 to 60 minutes before incision.[25,26]

Reconstructive surgeons often implant prosthetic material into patients. In the case of abdominal wall reconstruction, mesh infection may be decreased by antibiotic presoaking of the mesh. In an animal model, presoaking synthetic mesh in vancomycin for 15 minutes and then contaminating them with methicillin-resistant *Staphylococcus aureus* before implanting them in rats reduced mesh infection significantly more than presoaking in saline.[27] Newer prosthetic meshes have antibiotics incorporated into them, and have been shown to resist infection in vitro and in animals.[28,29] However, human studies are needed to further establish their efficacy. It is clear, however, that the most important step to minimize infection of a prosthetic material is the use of meticulous sterile technique. Exposure of the implant to the atmosphere, the patient's skin, and the surgical gloves should be minimized,[30] as these are all potential sources of contamination.

**Nutrition**

Plastic surgeons often encounter patients with nutritional deficiencies. One example is patients who have undergone bariatric surgery who present for body contouring. Agha-Mohammadi and Hurwitz found that patients with a history of

bariatric surgery are at higher risk of having low prealbumin, low vitamin A, and low hemoglobin compared with those without prior bariatric surgery.[31]

Protein deficiency translates into a higher risk of wound healing complications. Dunne et al. found that patients with low albumin had a 10-fold increase in the risk of surgical-site infection in abdominal wall reconstruction.[32] Specific deficiencies in the amino acids arginine and glutamine are associated with compromised wound healing. This is because synthesis of these amino acids is insufficient during the periods of increased protein turnover that occur during wound healing.[33,34]

In addition to the importance of proteins, carbohydrates are the major source of fuel for wound healing. It has been estimated that a wound with a surface area of 3 $cm^2$ and a depth of 1 mm requires 900 kcal to produce the requisite collagen.[35] When glucose is not adequately supplied, the liver increases gluconeogenesis, using proteins to manufacture carbohydrates. Most postoperative patients will eagerly resume a diet when allowed, but it is important to provide the nothing-by-mouth patient with an adequate source of glucose to prevent starvation ketosis. In adults, ketosis is prevented with a minimum of 50 to 100 g of glucose daily, the amount present in 1 to 2 liters of 5% dextrose in water.[36] Perioperative hypocaloric nutrition has been shown to inhibit endogenous protein breakdown and increase hepatic albumin synthesis.[37]

Some other micronutrients that have been implicated in wound healing include omega-3 fatty acids, vitamin C, vitamin A, zinc, and magnesium. Omega-3 fatty acids have demonstrated anti-inflammatory properties that may assist in wound healing: Lu et al. found enhanced wound closure and increased granulation tissue in mice supplemented with omega-3 fatty acids.[38] In humans, enteral omega-3 fatty acids have been found to have positive effects on the healing of pressure ulcers.[39] Vitamin C is a co-substrate for hydroxylase enzymes required for collagen formation, which may be abnormal in hernia patients. However, supplementation in nondeficient patients has not been conclusively shown to be beneficial for wound healing.[40,41] Vitamin A, in contrast, has been shown to improve epithelialization and collagen synthesis in nondeficient humans and animals, namely, those treated with corticosteroids.[42] Vitamin A does not, however, reverse corticosteroids' harmful effects on wound contraction or infection.[43] The recommended dose of vitamin A in patients on corticosteroids is 25,000 IU by mouth daily preoperatively and for 4 days postoperatively. Zinc is a cofactor for RNA and DNA polymerase, and its deficiency decreases wound strength and epithelialization. Magnesium functions as a cofactor in enzymes required for protein and collagen synthesis. Supplementation of zinc and magnesium in patients without deficiency lacks proven benefit.[44]

The harmful effects of malnutrition are not limited to wound healing complications. Kudsk et al. found that in patients undergoing elective abdominal surgery, mortality increased significantly when serum albumin decreased.[45] Patients in the lowest serum albumin group (<1.75 mg/dl) had a mortality rate of 31 percent, compared to a mortality rate of 2 percent in patients in the highest serum albumin group (>4.25 mg/dl). This has been confirmed in multiple other studies.[46,47] In fact, in a prospective, 44-center evaluation of 87,078 surgical patients, Khuri et al. found low albumin to be the most significant predictor of 30-day mortality, ahead of other variables such as emergency surgery and chronic obstructive pulmonary disease.[48] It should be noted that low serum albumin is a good marker for malnutrition in clinically stable patients, but is not as reliable in acutely ill patients, whose hypoalbuminemia may be attributable to elevated levels of interleukin-6 and tumor necrosis factor-α.[49]

The increasing risk of wound healing complications, major complications, and death in patients with malnutrition has been shown to be modifiable preoperatively. In several randomized controlled trials examining malnourished patients, those who were randomized to receive total parenteral nutrition preoperatively had significantly lower rates of noninfectious[50] and infectious[51] complications than those who did not receive total parenteral nutrition preoperatively.

**Smoking**

Cigarette smoke contains over 4000 constituents, of which nicotine, carbon monoxide, and hydrogen cyanide contribute principally to disturbances in the normal pathway of wound healing.[52] Nicotine acts as a vasoconstrictor, resulting in local ischemia. One cigarette results in a mean reduction in blood-flow velocity of 42 percent in digital vessels.[53] In addition, carbon monoxide, with a binding affinity 200 times greater than oxygen, binds to hemoglobin and reduces oxygen delivery to the wound. Hydrogen cyanide inhibits oxidative metabolism and oxygen transport.[54]

In a systematic review of 177 articles, Sørensen described the physiologic effects of smoking, and whether those effects were reversible by smoking cessation.[55] End-organ perfusion decreases, because of increased platelet aggregation, vasoconstriction, and endothelial dysfunction. Resistance to infection decreases, because of decreasing neutrophil function and oxidative burst. Wound healing is impaired because of decreasing fibroblast function, impaired epidermal proliferation, and enhanced matrix metalloproteinase activity. These physiologic effects lead to significant increases in the rates of wound healing complications after surgery. Finan et al. found that smoking increased the risk of wound infections in abdominal wall reconstruction 2.5-fold.[56] Others authors have found smokers to have increased rates of mesh-related infections,[57,58] wound healing problems after abdominoplasty,[59] and umbilical necrosis in patients undergoing autologous breast reconstruction.[60]

The increased risk of wound healing complications has been shown to be reversible with smoking cessation for 4 weeks preoperatively and postoperatively.[61] In a multicenter, randomized, controlled trial, Møller et al. found that preoperative and postoperative smoking cessation decreased overall complications (18 percent versus 52 percent; $p = 0003$) and infectious complications (4 percent versus 23 percent; $p = 0.001$).[62] In fact, patients who stop using tobacco before and after surgery have rates of infection and dehiscence similar to those who have never smoked.[63]

Noncompliance with smoking cessation before surgery should result in cancellation of the operation.[61] Unfortunately, nicotine is one of the most addictive substances known to humans, and relapse is common. Nicotine replacement therapy is commonly prescribed to assist with nicotine addiction, but its overall effects on wound healing are not clear.[64]

### Glucose Control

Hyperglycemia results in the modification and dysfunction of proteins and enzymes.[65] Diabetics have decreased fibroblast activity, decreased vascular endothelial growth factor expression, and higher levels of matrix metalloproteinases.[66] They are also predisposed to microvascular and macrovascular disease, which can impair blood flow and oxygen delivery.[67] Impairment of the immune system also makes diabetics more prone to postoperative infections.[68,69]

Endara et al. found that patients with even one instance of preoperative or postoperative blood glucose above 200 mg/dl were at significantly higher risk of dehiscence.[70] Moreover, the risk of surgical-site infection worsens with the degree of hyperglycemia.[71] In fact, Ramos et al. found that for every 40-mg/dl increase in postoperative blood glucose above 110 mg/dl, the risk of surgical-site infection increased 30 percent.[72] The harmful effects of hyperglycemia have also been demonstrated in patients undergoing abdominal wall reconstruction.[73]

Beginning with the preoperative appointment, glucose control should be discussed with the diabetic patient. Hemoglobin A1C levels may be useful in assessing the patient's recent glucose control. Prompt referral to an endocrinologist for preoperative optimization may be warranted.

Complications related to hyperglycemia can be prevented with adequate glucose control. In cardiac surgery patients, tight glucose control improves survival and decreases wound complications.[74] Although this has been balanced by reports of increased risks of hypoglycemia associated with aggressive glucose control,[75,76] previously acceptable glucose levels of greater than 200 mg/dl are almost uniformly associated with worse outcomes and should be avoided.[77]

### Homeopathic Medications

A careful preoperative history must ask patients about any homeopathic medications they may be taking but which they may have neglected to mention. A survey of 100 patients undergoing cosmetic surgery found that 55 percent of them used herbal supplements, a rate much higher than that of the general public (24 percent).[78] Most of those supplements have potential for perioperative bleeding, sedation, or hypertension (Table 1), and should therefore be discontinued 2 to 3 weeks preoperatively.[78–80]

### Operating Room Safety

The use of comprehensive, standardized checklists before incision, in which all members of the operating room team participate, has been shown to reduce the incidence of wrong-side surgery, surgical fires, and retained surgical items.[81,82] Checklists are capable of catching major errors before they occur.[83]

### Sutures and Mesh

In abdominal wall reconstruction, the classic recommendation is for fascial incisions to be

**Table 1. Most Commonly Used Homeopathic Medications and Herbs, and Their Effects***

| Homeopathic Medication | Effect |
|---|---|
| Immune effects | |
| Echinacea | Immunosuppression; infection |
| Hematologic effects | |
| Garlic | Platelet dysfunction |
| Ginkgo biloba | Platelet dysfunction |
| Cardiovascular effects | |
| Ginseng | Hypertension |
| St. John's wort | Hypotension; serotonin syndrome (if combined with serotonergic drugs) |
| Ephedra | Hypertension, myocardial infarction |
| Neurologic effects | |
| Kava | Sedation |

*From Hodges PJ, Kam PC. The peri-operative implications of herbal medicines. *Anaesthesia* 2002;57:889–899; Heller J, Gabbay JS, Ghadjar K, et al. Top-10 list of herbal and supplemental medicines used by cosmetic patients: What the plastic surgeon needs to know. *Plast Reconstr Surg.* 2006;117:436–445.

closed using a suture length–to–wound length ratio of at least 4:1.[84] This can be performed using small, frequent stitches or with larger bites at greater intervals. In a randomized controlled trial, Millbourn et al. determined that larger bites (>10 mm from the wound edge) were associated with a higher rate of hernia and surgical-site infection than smaller bites (5 to 8 mm from the wound edge).[85] Larger bites probably cause increased ischemia within the fascial closure.

Continuous sutures have been associated with fewer wound infections, and fewer hernia recurrences, than interrupted sutures.[86] Braided sutures are easier to handle but may increase the rate of wound infection, as bacteria are allowed to burrow between filaments.[87,88] Recently, triclosan-impregnated sutures have been introduced in an effort to decrease surgical-site infections, but the data on their efficacy are mixed.[89–91] When absorbable sutures are chosen, attention should be paid to the anticipated time to resorption, as short-lived suture may not provide adequate support during the healing process. A review of 15 studies on midline laparotomies found a higher rate of incisional hernias with continuous rapidly absorbable suture, compared with continuous slowly absorbable suture.[92] Nonabsorbable sutures resulted in a higher incidence of suture sinuses.

### Pain Control

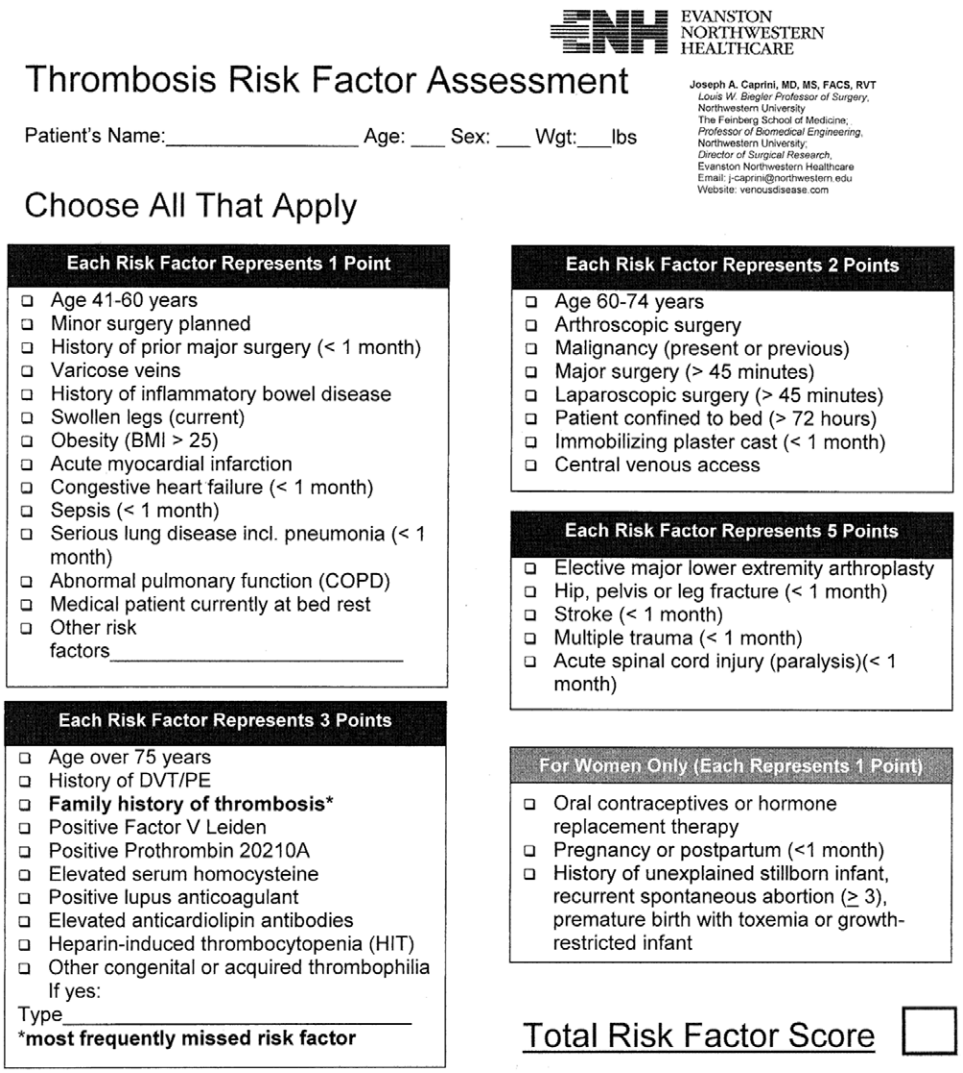
Uncontrolled postoperative pain limits patient mobility, decreases respiratory effort, and increases sympathetic discharge, which may decrease blood flow to healing tissues.[93] In a study of female gastric bypass patients, postsurgical pain intensity was associated with delayed wound healing.[94] These complications can be limited by preemptive analgesia with intraoperative local anesthetic infiltration or epidural catheters. Local infiltration is safe and effective, and has not been shown to impair wound healing.[95] When used in combination with spinal anesthesia, local nerve blocks lead to improved postoperative analgesia and earlier hospital discharge.[96] Transversus abdominis plane blocks and catheters may also be considered in abdominal wall reconstruction, as they reduce postoperative narcotic requirements, nausea, and vomiting.[97] Longer term pain relief may also be provided using liposomal bupivacaine.[98]

Studies have demonstrated that the use of elasticized abdominal binders may help control pain and increase ambulation.[99] Their effect on pulmonary function has been questioned, but a randomized study found no decrease in vital capacity among patients treated with a binder, and a moderate decrease in pain level.[100] Their use in patients at high risk for venous thromboembolism, however, should be judicious, as they have been shown to increase lower extremity venous stasis.[101,102]

### Topical Wound Management

At the conclusion of a surgical procedure, the surgeon has the choice of a multitude of dressing options, few of which have been shown to be superior to others. One option, however, has strong clinical evidence behind it: incisional negative-pressure wound therapy. In a retrospective cohort study, Condé-Green et al. found that abdominal wall reconstruction patients treated with incisional negative-pressure wound therapy had significantly fewer instances of wound healing complications (22 percent versus 63.6 percent; $p = 0.02$) and dehiscence (9 percent versus 39 percent; $p = 0.014$) than patients treated with standard dressings.[103] These findings have been replicated in patients undergoing median sternotomies,[104] groin vascular surgery incisions,[105] and fixation of high-risk lower extremity fractures.[106]

Open wounds that are not candidates for immediate closure may be managed with traditional dressings or negative-pressure wound therapy. In an animal study, Morykwas et al. showed that negative-pressure wound therapy increased blood flow and granulation tissue formation significantly more than traditional dressings.[107] The maximal increase in blood flow occurred for 5 to 7 minutes after negative pressure was applied.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Thrombosis Risk Factor Assessment

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Patient's Name:_____ Age: ___ Sex: ___ Wgt:___lbs

Choose All That Apply

**Each Risk Factor Represents 1 Point**

- ❑ Age 41-60 years
- ❑ Minor surgery planned
- ❑ History of prior major surgery (< 1 month)
- ❑ Varicose veins
- ❑ History of inflammatory bowel disease
- ❑ Swollen legs (current)
- ❑ Obesity (BMI > 25)
- ❑ Acute myocardial infarction
- ❑ Congestive heart failure (< 1 month)
- ❑ Sepsis (< 1 month)
- ❑ Serious lung disease incl. pneumonia (< 1 month)
- ❑ Abnormal pulmonary function (COPD)
- ❑ Medical patient currently at bed rest
- ❑ Other risk factors_____

**Each Risk Factor Represents 2 Points**

- ❑ Age 60-74 years
- ❑ Arthroscopic surgery
- ❑ Malignancy (present or previous)
- ❑ Major surgery (> 45 minutes)
- ❑ Laparoscopic surgery (> 45 minutes)
- ❑ Patient confined to bed (> 72 hours)
- ❑ Immobilizing plaster cast (< 1 month)
- ❑ Central venous access

**Each Risk Factor Represents 5 Points**

- ❑ Elective major lower extremity arthroplasty
- ❑ Hip, pelvis or leg fracture (< 1 month)
- ❑ Stroke (< 1 month)
- ❑ Multiple trauma (< 1 month)
- ❑ Acute spinal cord injury (paralysis)(< 1 month)

**Each Risk Factor Represents 3 Points**

- ❑ Age over 75 years
- ❑ History of DVT/PE
- ❑ **Family history of thrombosis***
- ❑ Positive Factor V Leiden
- ❑ Positive Prothrombin 20210A
- ❑ Elevated serum homocysteine
- ❑ Positive lupus anticoagulant
- ❑ Elevated anticardiolipin antibodies
- ❑ Heparin-induced thrombocytopenia (HIT)
- ❑ Other congenital or acquired thrombophilia

If yes:
Type_____
***most frequently missed risk factor**

**For Women Only (Each Represents 1 Point)**

- ❑ Oral contraceptives or hormone replacement therapy
- ❑ Pregnancy or postpartum (<1 month)
- ❑ History of unexplained stillborn infant, recurrent spontaneous abortion (≥ 3), premature birth with toxemia or growth-restricted infant

Total Risk Factor Score ☐

**Fig. 1.** The 2005 Caprini scale. (Reprinted from Caprini JA. Thrombosis risk assessment as a guide to quality patient care. Dis Mon. 2005;51:70–78, with permission from Elsevier.)

Consequently, negative pressure applied intermittently for 5 minutes, interspersed with 2 minutes of no negative pressure, resulted in the greatest amount of granulation tissue formation. They also demonstrated that negative-pressure wound therapy decreased bacterial counts. This translates clinically into improved wound healing outcomes with negative-pressure wound therapy. In a multicenter study, Armstrong et al. randomized patients with diabetic foot wounds to negative-pressure wound therapy versus standard dressings.[108] At 16 weeks, significantly more wounds treated with negative-pressure wound therapy were healed.

**Postoperative Care**

Additional simple interventions can avoid major postoperative complications. All patients who have undergone general anesthesia have some degree of atelectasis and should start pulmonary physiotherapy in the recovery room. Zoremba et al. randomized 60 obese surgical patients to incentive spirometry starting in recovery, versus no incentive spirometry.[109] The incentive spirometry group had significantly improved oxygenation, functional vital capacity, and peek inspiratory flow compared with the control group. This translates into real clinical outcome improvement. In a prospective cohort study, surgical patients who started incentive spirometry in recovery had shorter length of stay in the intensive care unit (3.1 days versus 4 days; $p = 0.03$) and fewer pulmonary complications (6 percent versus 17 percent; $p = 0.01$).[110]

For non–implant-based operations with no signs of infection, postoperative antibiotics should not be used beyond the immediate perioperative period, as prolonged antibiotic prophylaxis has

not been shown to be effective, and may promote resistant organisms.[111–113] In implant-based operations, some studies have shown some utility of postoperative prophylactic antibiotics,[114] and further studies to determine the optimal length of prophylaxis for those cases are needed.

Closed-suction drains help seal potential spaces, preventing them from developing fluid collections. However, they can act as an ascending conduit for infection. Some authors have advocated the use of chlorhexidine-impregnated patches (Biopatch; Johnson & Johnson Wound Management, Somerville, N.J.) around drain exit sites. Those patches have been shown to be effective at reducing infections related to vascular and epidural catheters,[115] and at minimizing contamination of closed-suction drains in breast surgery.[116] There is little clinical evidence, however, that they reduce the risk of surgical-site infections in plastic surgery, specifically when prosthetic implants are used.[117]

### Venous Thromboembolism Prevention

An essential intervention in all surgical patients is the application of sequential compression devices on the lower extremities at all times when not ambulating, as this has been shown to significantly decrease deep venous thrombosis.[118] In addition, high-risk surgical patients undergoing general anesthesia should be considered for chemoprophylaxis,[119,120] which has been shown to be effective[121,122] and safe.[123] The 2005 Caprini risk model serves as a useful risk-stratification scheme for plastic surgery patients and can help guide the surgeon when choosing the appropriate venous thromboembolism prevention regimen (Fig. 1).[124]

## CONCLUSIONS

The goal of every reconstructive operation is a satisfied, well-healed patient who does not require hospital readmission or return to the operating room. Complications in reconstructive surgery, ranging from surgical-site infection to patient dissatisfaction, pneumonia, and death, can be reduced by thoughtful preoperative patient assessment and optimization.

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