

Complications of Postmastectomy Breast Reconstructions in Smokers, Ex-smokers, and Nonsmokers

Arvind N. Padubidri, M.D., Randall Yetman, M.D., Earl Browne, M.D., Armand Lucas, M.D., Frank Papay, M.D., Brett Larive, M.S., and James Zins, M.D.

Cleveland, Ohio

Smoking results in impaired wound healing and poor surgical results. In this retrospective study, we compared outcomes in 155 smokers, 76 ex-smokers, and 517 nonsmokers who received postmastectomy breast reconstructions during a 10-year period. Ex-smokers were defined as those who had quit smoking at least 3 weeks before surgery.

Transverse rectus abdominis musculocutaneous (TRAM) flap surgery was performed significantly less often in smokers (24.5 percent) than in ex-smokers (30.3 percent) or nonsmokers (39.1 percent) ($p < 0.001$). Tissue expansion followed by implant was performed in 112 smokers (72.3 percent), 50 (65.8 percent) ex-smokers, and 304 nonsmokers (58.8 percent) ($p = 0.002$).

The overall complication rate in smokers was 39.4 percent, compared with 25 percent in ex-smokers and 25.9 percent in nonsmokers, which is statistically significant ($p = 0.002$). Mastectomy flap necrosis developed in 12 smokers (7.7 percent), 2 ex-smokers (2.6 percent), and 8 nonsmokers (1.5 percent) ($p < 0.001$). Among patients receiving TRAM flaps, fat necrosis developed in 10 smokers (26.3 percent), 2 ex-smokers (8.7 percent), and 17 nonsmokers (8.4 percent). Abdominal wall necrosis was more common in smokers (7.9 percent) than in ex-smokers (4.3 percent) or nonsmokers (1.0 percent).

In this large series, tissue expansion was performed more often in smokers than was autogenous reconstruction. Complications were significantly more frequent in smokers. Mastectomy flap necrosis was significantly more frequent in smokers, regardless of the type of reconstruction. Breast reconstruction should be done with caution in smokers. Ex-smokers had complication rates similar to those of nonsmokers. Smokers undergoing reconstruction should be strongly urged to stop smoking at least 3 weeks before their surgery. (*Plast. Reconstr. Surg.* 107: 342, 2001.)

Smoking has well-documented adverse effects on wound healing, oxygen delivery, and blood flow in tissues. Numerous clinical studies

have substantiated that cigarette smokers are at increased risk for problems with wound healing.^{1,2}

Compromised wound healing is a particular concern in smokers undergoing breast reconstructive surgery. The incidence of complications in wound healing after breast surgery is significantly higher in smokers than in nonsmokers.³⁻⁶

Smoking was identified as a risk factor for flap necrosis in patients undergoing transverse rectus abdominis musculocutaneous (TRAM) flap breast reconstruction,^{4,7} and as a result, some centers simply exclude smokers from candidacy for such procedures. However, some other studies have found no major differences in complication rates in smokers and nonsmokers, and the authors of these studies do not consider smoking a contraindication to TRAM flaps.^{8,9}

In his experience with 227 patients, Kroll¹⁰ found that abdominal wall necrosis was more common in current and former smokers (27.5 percent) than in nonsmokers (5.9 percent). Current smokers had higher risks than ex-smokers, who in turn had higher risks than nonsmokers did. He defined ex-smokers as those who had smoked in the past but had quit at least 12 months earlier.

Thus, controversy still exists about the safety of autogenous breast reconstructions in active smokers. The purpose of our study was to clarify the issues by comparing the results of the various types of breast reconstructions in active smokers, ex-smokers, and nonsmokers. To our

knowledge, this is the largest study of smoking as a risk factor in breast reconstruction.

PATIENTS AND METHODS

All patients at the Cleveland Clinic Foundation who had undergone reconstruction after mastectomy using either prostheses or autogenous tissue between 1988 and 1997 were included in the study. Different options of breast reconstruction were discussed with each patient. The selection criteria varied because there were six different plastic surgeons who performed the reconstruction. In the early part of the study, reconstruction using tissue expanders was the most commonly performed operation. From 1993 onward, autogenous reconstruction using TRAM flap was the reconstructive method of choice. There was no selection bias in the type of TRAM flap chosen (free versus pedicled) in the three groups.

We defined active smokers as those who smoked at the time of surgery. Smokers were asked to quit smoking when they were first seen in the Outpatient Clinic. Elective surgery usually was scheduled after 3 weeks. Patients who reported that they had quit smoking 3 weeks or more before surgery were classified as ex-smokers. Nonsmokers were those who reported never smoking.

The patient data were obtained through review of hospital records and photographs. Data compiled (using Epi-Info 6.04 software) included patient and tumor characteristics, smoking history, type of reconstruction, complications, and the number of procedures required to obtain the final result.

Complication and treatment rates were compared between smoking status groups using Mantel-Haenszel tests for general association. The test examined whether the response variables (complications, Y/N, or treatment, Y/N) were associated in nonspecific ways among the smoking status levels. The null hypothesis held that there would be no association among the levels. Post hoc comparisons were made using chi-square tests with Bonferroni adjustments to the alpha levels. No *p* values were estimated for component subgroup comparisons because no prior hypothesis had been made concerning their distribution and because the number of events for these subcategories was quite small. All tests were two-sided. Statistical analysis was performed using Statistical Analysis Software (Cary, N.C.).

RESULTS

Of the 748 patients who underwent breast reconstruction, 155 (20.7 percent) were active smokers, 76 (10.2 percent) were ex-smokers, and 517 (69.1 percent) were nonsmokers. The mean age of active smokers was 47.7 years (range, 30 to 76), of ex-smokers, 50.1 years (range, 14 to 73), and of nonsmokers, 49.4 years (range, 24 to 77). The mean length of stay in the hospital was 3.45 days (range, 1 to 10) for active smokers, 3.35 days (range, 1 to 7) for ex-smokers, and 3.75 days (range, 1 to 25) for nonsmokers.

TRAM flap surgery was performed significantly more often among nonsmokers (Table I) than among smokers or ex-smokers. Tissue expansion followed by implant was the reconstruction method used most frequently for smokers and was used significantly less often in the other groups.

Immediate reconstruction was performed in 144 smokers (92.9 percent), 65 ex-smokers (85.5 percent), and 466 nonsmokers (90.1 percent). Eleven smokers, 9 ex-smokers, and 51 nonsmokers underwent bilateral breast reconstruction.

The overall complication rate was 39.4 percent (61 of 155) in active smokers. This was significantly higher than the rates of 25 percent (19 of 76) for ex-smokers and 25.9 percent (134 of 517) for nonsmokers ($p = 0.002$). Mastectomy flap necrosis was significantly more frequent in active smokers (Fig. 1). Twelve smokers (7.7 percent), two ex-smokers (2.6 percent), and eight nonsmokers (1.5 percent) developed such necrosis ($p < 0.001$).

Implants/Expanders

Among the 481 patients who had reconstructions with prostheses, 116 were smokers, 53 were ex-smokers, and 312 were nonsmokers. Prosthetic reconstructions were complicated by mastectomy flap (native breast skin) necro-

TABLE I
Frequency of Reconstruction Procedures in 748 Breast Reconstruction Patients

Reconstruction Type	Smokers (<i>n</i> = 155) <i>n</i> (%)	Ex-smokers (<i>n</i> = 76) <i>n</i> (%)	Nonsmokers (<i>n</i> = 517) <i>n</i> (%)	<i>p</i> Value
TRAM flap	38 (24.5)	23 (30.3)	202 (39.1)	<0.001
Latissimus flap	1 (0.6)	0	3 (0.6)	0.97
Implants	4 (2.6)	3 (3.9)	8 (1.5)	0.30
Tissue expander	112 (72.3)	50 (65.8)	304 (58.8)	0.002

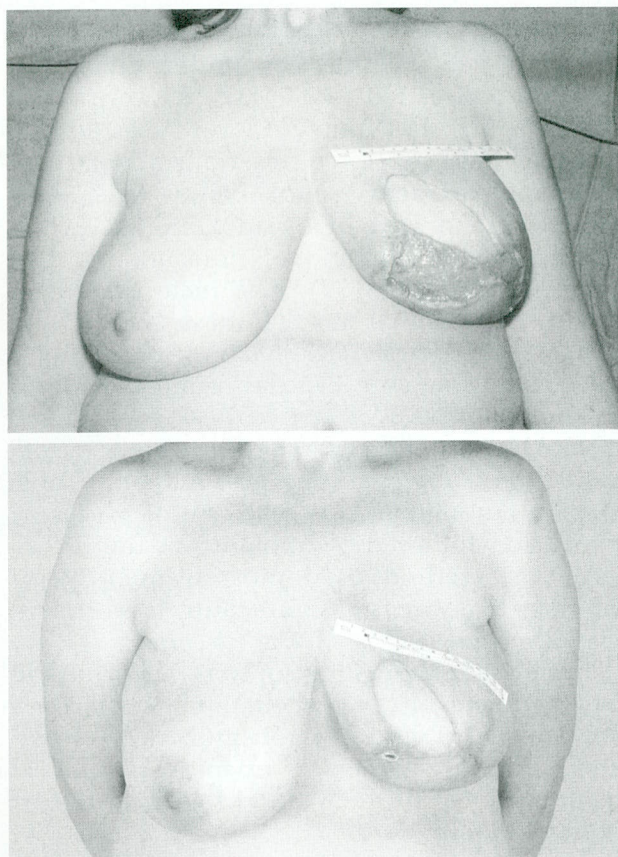


FIG. 1. (Above) Mastectomy flap necrosis, pictured in a 51-year-old smoker, 3 weeks after surgery. Necrotic skin has already been debrided. (Below) Complete healing seen here because of secondary intention, after 6 weeks.

sis, capsular contracture, infection, wound dehiscence, seroma, and hematoma (Table II). Complications were significantly more common in smokers (37.1 percent) than in ex-smokers (24.5 percent) and nonsmokers (26.6 percent) ($p = 0.05$). Mastectomy flap necrosis was more common in smokers than in ex-smokers and nonsmokers. We also noted a

TABLE II
Complications in Smokers, Ex-smokers, and Nonsmokers
Who Received Implants and Tissue Expanders

	Smokers (<i>n</i> = 116) <i>n</i> (%)	Ex-smokers (<i>n</i> = 53) <i>n</i> (%)	Nonsmokers (<i>n</i> = 312) <i>n</i> (%)	<i>p</i> Value
Complications (patients)	43 (37.1)	13 (24.5)	83 (26.6)	0.05
Complications (type)				
Seroma	6 (5.2)	3 (5.7)	8 (2.6)	
Hematoma	2 (1.7)	0	2 (0.6)	
Infection	5 (4.3)	5 (9.4)	13 (4.2)	
Mastectomy flap necrosis	9 (7.8)	1 (1.9)	4 (1.3)	
Wound dehiscence	1 (0.9)	0	1 (0.3)	
Capsule	28 (24.1)	8 (15.1)	51 (16.3)	

higher incidence of capsular contracture (Baker's grades III and IV) in smokers than in ex-smokers or nonsmokers.

TRAM Flaps

Among those who had TRAM flap reconstruction, complications were significantly more common in smokers (Table III). Partial flap necrosis, defined as necrosis of a significant portion of the flap requiring debridement in the operating room, did not develop at different rates in the three groups (Fig. 2). Necrosis of the anterior abdominal wall was seen typically in the infraumbilical region, which occasionally involved the umbilicus as well, and it was more frequent among smokers (Fig. 3). Fat necrosis (an area of thickening, firmness, irregularity, or a draining sinus) also developed more frequently in smokers (Fig. 4). Furthermore, the incidence of mastectomy flap necrosis was higher in smokers. Secondary revision procedures after TRAM flap reconstruction, either for scar revision or for reshaping the flap with excision or liposuction, did not occur more frequently in smokers.

We compared the complications in the three groups with only unipedicle TRAM flaps (Table IV). The complication rate was higher in smokers. The incidence of abdominal hernia (Fig. 5) and mastectomy flap necrosis was higher in smokers.

Eighteen double-pedicle TRAM flaps were performed in this series (Table V). The overall complication rate was higher in smokers. Next, we looked at free TRAM flaps and found that the complication rates in the three groups were not different (Table VI). Finally, we compared the complication rates in smokers who received unipedicle, bipedicle, and free TRAMs (Table VII). There were no significant differences in the overall complication rates among the three groups.

DISCUSSION

Nicotine and carbon monoxide are the most potent toxins present in tobacco smoke that adversely affect tissue oxygenation and impair wound healing. Nicotine indirectly inhibits capillary blood flow by systemically releasing catecholamines.^{11,12} Carbon monoxide competitively inhibits the binding of oxygen, causing the oxyhemoglobin dissociation curve to shift to the left and decreasing the oxygen availability to tissues. Nonreversible vascular

TABLE III
Complications among Smokers, Ex-smokers, and
Nonsmokers Receiving TRAM Flaps

	Smokers (n = 38) n (%)	Ex-smokers (n = 23) n (%)	Nonsmokers (n = 202) n (%)	p Value
Complications (patients)	18 (47.4)	6 (26.1)	51 (25.2)	0.01
Complication (type)				
Seroma	3 (7.9)	0	13 (6.4)	
Hematoma	0	0	9 (4.5)	
Infection	3 (7.9)	0	10 (5.0)	
Partial necrosis	4 (10.5)	1 (4.3)	7 (3.5)	
Total necrosis	1 (2.6)	1 (4.3)	2 (1.0)	
Fat necrosis	10 (26.3)	2 (8.7)	17 (8.4)	
Hernia	4 (10.5)	2 (8.7)	9 (4.5)	
Mastectomy flap necrosis	3 (7.9)	1 (4.3)	4 (2.0)	
Abdominal wall necrosis	3 (7.9)	1 (4.3)	2 (1.0)	
Wound dehiscence	2 (5.3)	0	3 (1.5)	
Further surgery				
Scar revision	4 (10.5)	4 (17.4)	19 (9.4)	
TRAM revision	10 (26.3)	7 (30.4)	48 (23.8)	

occlusive changes consequent to cigarette smoking are less well documented.^{13,14}

Flap survival in animal models is impaired by exposure to tobacco smoke.¹⁵⁻¹⁷ Smokers have significantly greater wound problems and produce unacceptable scars.^{18,19} Smoking affects the survival of skin flaps and grafts.²⁰⁻²² Smoking has adverse sequelae after digital replantation.²³ In experimental studies, Gu et al.²⁴ demonstrated that cigarette smoking delayed the healing of endothelia at the anastomotic site of vessels and promoted platelet aggregation. However, in clinical microsurgery, anastomotic patency and flap survival rates are not different in smokers.^{25,26} We also did not find any significant differences in complications in the three groups with free TRAM reconstruction.

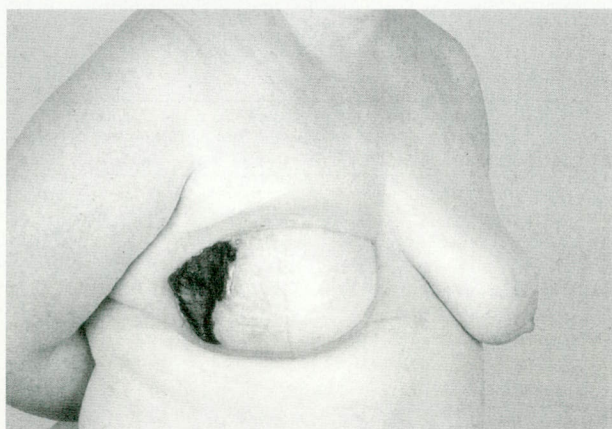


FIG. 2. Partial necrosis in a pedicled TRAM flap seen here in a 49-year-old smoker, 17 days after operation.

Breast reconstruction after mastectomy involves extensive dissection of tissue, and skin survival depends on well-vascularized flaps. In our study, the overall complication rate among smokers was significantly higher than in other groups, but the risk for ex-smokers was no greater than that of nonsmokers.

Smoking is one of the significant predisposing factors for development of skin problems in prosthetic reconstruction.²⁷ We found an overall high incidence of complications in active smokers undergoing implant or expander reconstruction. Capsular contracture (Baker's grades III and IV) occurred somewhat more frequently in smokers. Smoking may be one of the contributing factors for the development of capsule.

Currently, autogenous reconstruction with TRAM flaps is the most popular method of breast reconstruction. We noticed a higher complication rate in active smokers for unipedicle and bipedicle flaps. Partial flap loss and fat necrosis continue to be concerns for autogenous reconstructions, particularly in patients with high-risk factors.²⁸ Fat necrosis was more frequent among smokers in our study. Kroll et al.²⁹ reported that smokers developed fat necrosis more often than nonsmokers, but the trend was not statistically significant. However, in their group, smokers included both current and former smokers.

Surgical delay has been useful in operating on high-risk patients.^{30,31} Delay may reduce flap-related complications in high-risk patients such as smokers, but it will not address the issue of necrotic complications in the native breast skin and abdominal wall.

Various studies have shown that smokers have an increased risk of developing necrosis of native breast skin after mastectomy.^{32,33} In our series, mastectomy flap necrosis was a significant problem in active smokers. This adds greatly to the morbidity of the reconstruction, and sometimes it can delay the commencement of adjuvant radiotherapy or chemotherapy. With the increasing popularity of skin-sparing mastectomy, mastectomy flap necrosis may become more of a problem. A skin-sparing mastectomy is technically more demanding than a traditional mastectomy, requiring wide undermining of breast skin, meticulous surgical technique, and gentle handling of tissues to prevent skin flap ischemia. The oncologic surgeon should be aware of this problem and execute more caution when operating on ac-

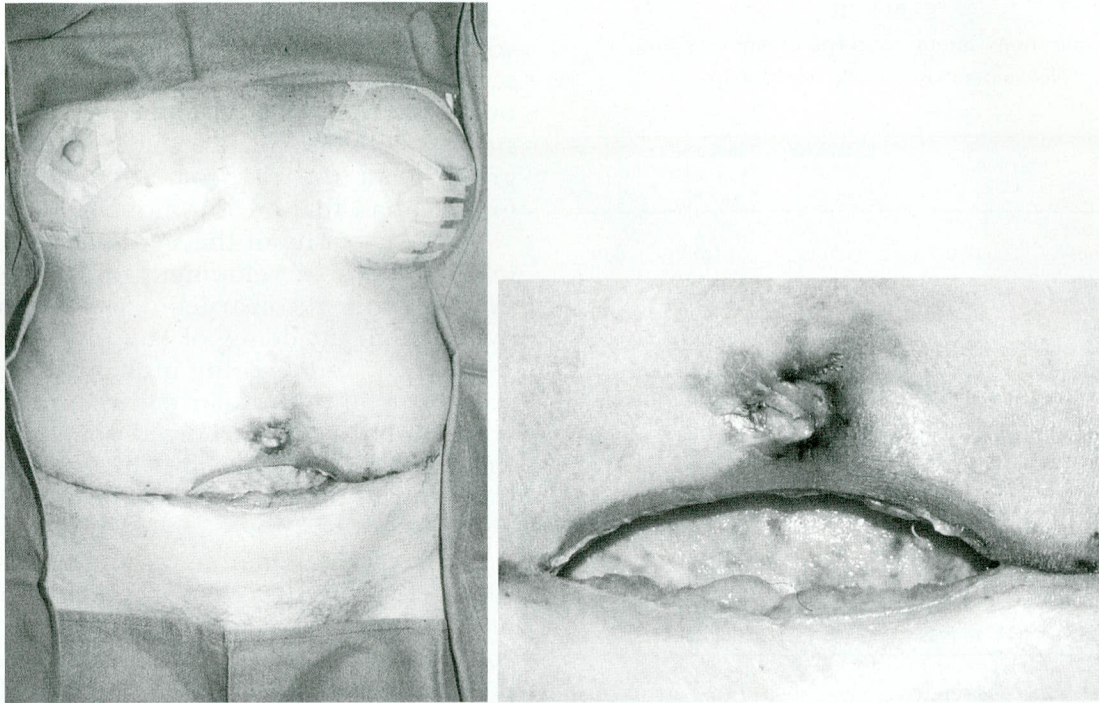


FIG. 3. (Left) Infraumbilical (abdominal wall) full-thickness necrosis in a 43-year-old chronic smoker, after a pedicled TRAM flap reconstruction of left breast. The patient also underwent a right-breast reduction. (Right) Same patient with a close-up view of the necrosis.

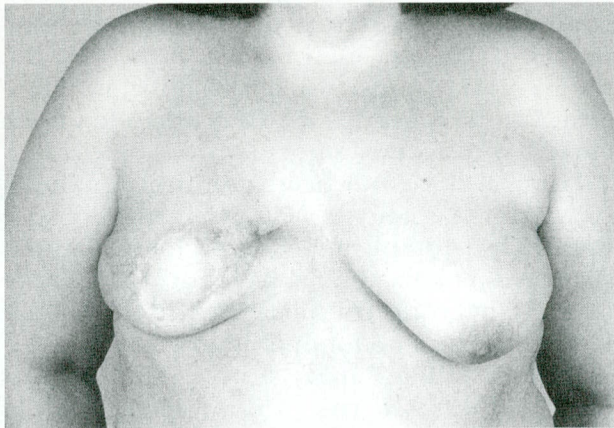


FIG. 4. Fat necrosis resulting in a significant loss of volume and contour deformity of the right TRAM flap, in a 46-year-old woman who smoked for 20 years.

tive smokers. Some surgeons routinely use intraoperative fluorescein in these high-risk patients to help delineate the ischemic areas.

Another area of concern is the abdominal skin below the umbilicus.³⁴ We found more abdominal wall necroses in smokers than in other patients. Thus, complications associated with mastectomy flap and the abdominal wall are a real risk in active smokers. These flaps are widely undermined and depend on a random blood supply unlike the axial vascular source of the TRAM flap. Conservative undermining in

face-lift surgery has decreased the rate of skin sloughs in smokers.³⁵ Ischemic complications of the mastectomy skin flap and the abdominal wall can be prevented to some extent by paying meticulous attention to the dissection of these flaps, maintaining adequate thickness of flaps, and avoiding overenthusiastic retraction.

Smokers also tend to cough more than nonsmokers, and postoperative coughing can increase the possibility of hematomas and hernia. Watterson et al.³⁶ showed that smoking at

TABLE IV
Complications in Smokers, Ex-smokers, and Nonsmokers
Who Received Unipedicle TRAM Flaps

	Smokers (n = 26) n (%)	Ex-smokers (n = 20) n (%)	Nonsmokers (n = 152) n (%)	p Value
Complications (patients)	12 (46.2)	6 (30)	40 (26.3)	0.05
Complication (type)				
Infection	1 (3.8)	0	8 (5.3)	
Partial necrosis	3 (11.5)	1 (5)	6 (3.9)	
Total necrosis	0	1 (5)	1 (0.7)	
Fat necrosis	7 (26.9)	2 (10)	12 (7.9)	
Hernia	4 (15.4)	2 (10)	7 (4.6)	
Mastectomy flap necrosis	3 (11.5)	1 (5)	4 (2.6)	
Abdominal wall necrosis	1 (3.8)	1 (5)	2 (1.3)	
Wound dehiscence	2 (7.7)	0	2 (1.3)	

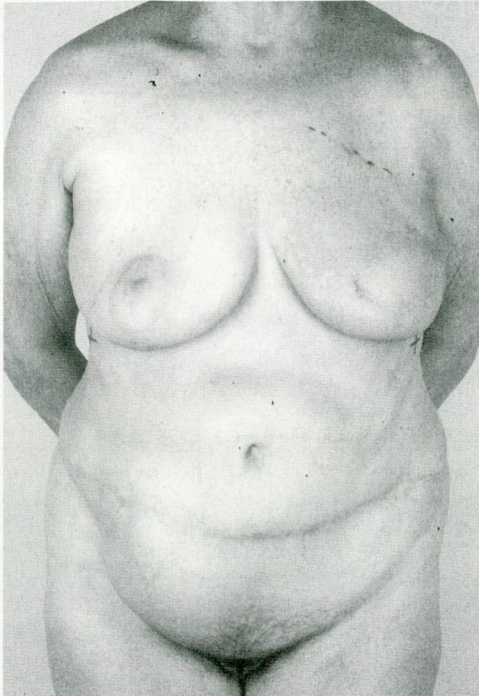


FIG. 5. A large ventral hernia in the right lower quadrant, pictured in a 57-year-old smoker who underwent a contralateral pedicled TRAM flap for left-breast reconstruction.

the time of surgery was a risk factor for the development of hernia. In our experience, the incidence of hernia was increased in active smokers undergoing unipedicle reconstructions.

No study has investigated the period of time necessary for cessation of smoking to have a positive effect on wound healing. Kinsella et al.³⁷ divided their patients into three groups—active smokers, ex-smokers (who had quit smoking 1 year before surgery), and nonsmokers. They showed that active smokers had higher complication rates in facial skin flap surgery. Smoking a single cigarette can produce skin vasoconstriction for up to 90 min-

TABLE V
Complications among Smokers, Ex-smokers, and Nonsmokers Receiving Bipedicule Flaps

	Smokers (n = 7) n (%)	Ex-smokers (n = 1) n (%)	Nonsmokers (n = 10) n (%)	p Value
Complications (patients)	4 (57.1)	0	1 (10)	0.04
Complication (type)				
Partial necrosis	1 (14.3)	0	0	
Total necrosis	0	0	0	
Fat necrosis	2 (28.6)	0	1 (10)	
Abdominal wall necrosis	2 (28.6)	0	0	

TABLE VI
Complications in Patients Receiving Free TRAM Flaps

	Smokers (n = 5) n (%)	Ex-smokers (n = 2) n (%)	Nonsmokers (n = 40) n (%)	p Value
Complications (patients)	2 (40)	0	10 (25)	0.63
Complication (type)				
Partial necrosis	0	0	1 (2.5)	
Total necrosis	1 (20)	0	1 (2.5)	
Fat necrosis	1 (20)	0	4 (10)	
Hernia	0	0	2 (5)	

utes.³⁸ Jensen et al.³⁹ demonstrated a rapid and significant reduction in the subcutaneous tissue oxygen tension after smoking a cigarette that lasted for 30 to 50 minutes. The degree of hypoxia was within the range associated with poor healing of wounds. The authors estimated that a typical one-pack-per-day smoker would have significant tissue hypoxia for 15 to 20 hours per day. Van Adrichem et al.⁴⁰ showed that during smoking the microcirculatory flow of skin decreases considerably and only recovers by half after 10 minutes of rest. The vasoconstrictive effect of nicotine usually lasts approximately 15 minutes after the cessation of smoking. But the hypoxic effect of cigarette smoke is more prolonged because of the high affinity between carbon monoxide and hemoglobin, and lasts for up to 48 hours. Platelet adhesiveness and blood viscosity may remain elevated beyond 24 hours.

Patients should be strongly encouraged to stop smoking when they are first seen in the office or when their surgery is scheduled. Prospective patients must be told about the clearly

TABLE VII
Complication Frequencies in Smokers Who Received Unipedicle, Bipedicule, or Free TRAMs

	Smokers with Unipedicle Flaps (n = 26) n (%)	Smokers with Bipedicle Flaps (n = 7) n (%)	Smokers with Free Flaps (n = 5) n (%)	p Value
Complications (patients)	14 (53.9)	4 (57.1)	2 (40)	0.83
Complication (type)				
Partial necrosis	3 (11.5)	1 (14.3)	0	
Total necrosis	0	1 (5)	1 (20)	
Fat necrosis	7 (26.9)	2 (28.6)	1 (20)	
Hernia	4 (15.4)	0	0	
Mastectomy flap necrosis	3 (11.5)	0	0	
Abdominal wall necrosis	1 (3.8)	2 (28.6)	0	

documented adverse effects of smoking on wound healing and survival of flaps. Because there is often a 2-week to 3-week delay before surgery is scheduled, we think that getting the patients to quit smoking works quite well from a practical standpoint as well. However, the minimal time that smoking should be avoided perioperatively is unknown. Recommendations vary from 1 day to 3 weeks preoperatively and from 5 days to 4 weeks postoperatively.²¹

Smokers undergoing reconstruction should be strongly urged to stop smoking at least 3 weeks before their surgery. This may provide some patients with an effective motivation to stop smoking. Our study clearly showed that smokers who had quit as little as 3 weeks before their surgery (ex-smokers) had complication rates similar to those of nonsmokers. Further research and prospective studies are needed to establish the effects on wound healing of terminating smoking before as well as after surgery.

Arvind N. Padubidri, M.D.
3715 Warrensville Center Road, #340
Shaker Heights, Ohio 44122
arvindp86@yahoo.com

ACKNOWLEDGMENTS

The authors thank Pat Shoda and Bobby Blazy (Medical Photography) and Kathy Cotman (Biostatistics) for their excellent technical assistance.

REFERENCES

1. Mosely, L. H., Finseth, F., and Goody, M. Nicotine and its effect on wound healing. *Plast. Reconstr. Surg.* 61: 570, 1978.
2. Goldminz, D., and Bennett, R. G. Cigarette smoking and flap and full-thickness graft necrosis. *Arch. Dermatol.* 127: 1012, 1991.
3. Miller, A. P., and Falcone, R. E. Breast reconstruction: Systemic factors influencing local complications. *Ann. Plast. Surg.* 27: 115, 1991.
4. Schefflan, M., and Kalisman, M. Complications of breast reconstruction. *Clin. Plast. Surg.* 11: 343, 1984.
5. Bailey, M. H., Smith, J. W., Casas, L., et al. Immediate breast reconstruction: Reducing the risks (see comments). *Plast. Reconstr. Surg.* 83: 845, 1989.
6. Holley, D. T., Toursarkissian, B., Vasconez, H. C., et al. The ramifications of immediate reconstruction in the management of breast cancer. *Am. Surg.* 61: 60, 1995.
7. Hartrampf, C. R., Jr., and Bennett, G. K. Autogenous tissue reconstruction in the mastectomy patient: A critical review of 300 patients. *Ann. Surg.* 205: 508, 1987.
8. Banic, A., Boeckx, W., Greulich, M., et al. Late results of breast reconstruction with free TRAM flaps: A prospective multicentric study. *Plast. Reconstr. Surg.* 95: 1195, 1995.
9. Jacobsen, W. M., Meland, N. B., and Woods, J. E. Autologous breast reconstruction with use of transverse rectus abdominis musculocutaneous flap: Mayo Clinic experience with 147 cases. *Mayo Clin. Proc.* 69: 635, 1994.
10. Kroll, S. S. Necrosis of abdominoplasty and other secondary flaps after TRAM flap breast reconstruction. *Plast. Reconstr. Surg.* 94: 637, 1994.
11. Waeber, B., Schaller, M. D., Nussberger, J., et al. Skin blood flow and cigarette smoking: The role of vasopressin. *Clin. Exp. Hypertens. Part A* 6: 2003, 1984.
12. Waeber, B., Schaller, M. D., Nussberger, J., et al. Skin blood flow reduction induced by cigarette smoking: Role of vasopressin. *Am. J. Physiol.* 247: H895, 1984.
13. Monfrecola, G., Riccio, G., Savarese, C., et al. The acute effect of smoking on cutaneous microcirculation blood flow in habitual smokers and nonsmokers. *Dermatology* 197: 115, 1998.
14. Tur, E., Yosipovitch, G., and Oren-Vulfs, S. Chronic and acute effects of cigarette smoking on skin blood flow. *Angiology* 43: 328, 1992.
15. Lawrence, W. T., Murphy, R. C., Robson, M. C., and Hegggers, J. P. The detrimental effect of cigarette smoking on flap survival: An experimental study in the rat. *Br. J. Plast. Surg.* 37: 216, 1984.
16. Reus, W. F., Robson, M. C., Zachary, L., and Hegggers, J. P. Acute effects of tobacco smoking on blood flow in the cutaneous micro-circulation. *Br. J. Plast. Surg.* 37: 213, 1984.
17. Craig, S., and Rees, T. D. The effects of smoking on experimental skin flaps in hamsters. *Plast. Reconstr. Surg.* 75: 842, 1985.
18. Abidi, N. A., Dhawan, S., Gruen, G. S., et al. Wound-healing risk factors after open reduction and internal fixation of calcaneal fractures. *Foot Ankle Int.* 19: 856, 1998.
19. Siana, J. E., Rex, S., and Gottrup, F. The effect of cigarette smoking on wound healing. *Scand. J. Plast. Reconstr. Surg. Hand Surg.* 23: 207, 1989.
20. Rees, T. D., Liverett, D. M., and Guy, C. L. The effect of cigarette smoking on skin-flap survival in the face lift patient. *Plast. Reconstr. Surg.* 73: 911, 1984.
21. Riefkohl, R., Wolfe, J. A., Cox, E. B., and McCarty, K. S., Jr. Association between cutaneous occlusive vascular disease, cigarette smoking, and skin slough after rhytidectomy. *Plast. Reconstr. Surg.* 77: 592, 1986.
22. Lovich, S. F., and Arnold, P. G. The effect of smoking on muscle transposition. *Plast. Reconstr. Surg.* 93: 825, 1994.
23. Harris, G. D., Finseth, F., and Buncke, H. J. The hazard of cigarette smoking following digital replantation. *J. Microsurg.* 1: 403, 1980.
24. Gu, Y. D., Zhang, G. M., Zhang, L. Y., et al. Clinical and experimental studies of cigarette smoking in microvascular tissue transfers. *Microsurgery* 14: 391, 1993.
25. Reus, W. F., III, Colen, L. B., and Straker, D. J. Tobacco smoking and complications in elective microsurgery. *Plast. Reconstr. Surg.* 89: 490, 1992.
26. Arnez, Z. M., Bajec, J., Bardsley, A. F., et al. Experience with 50 free TRAM flap breast reconstructions. *Plast. Reconstr. Surg.* 87: 470, 1991.
27. Camilleri, I. G., Malata, C. M., Stavrianos, S., and McLean, N. R. A review of 120 Becker permanent tissue expanders in reconstruction of the breast (see comments). *Br. J. Plast. Surg.* 49: 346, 1996.
28. Paige, K. T., Bostwick, J., III, Bried, J. T., and Jones, G. A comparison of morbidity from bilateral, unipedicled

- and unilateral, unipedicled TRAM flap breast reconstructions. *Plast. Reconstr. Surg.* 101: 1819, 1998.
29. Kroll, S. S., Gherardini, G., Martin, J. E., et al. Fat necrosis in free and pedicled TRAM flaps. *Plast. Reconstr. Surg.* 102: 1502, 1998.
30. Hudson, D. A. The surgically delayed unipedicled TRAM flap for breast reconstruction (see comments). *Ann. Plast. Surg.* 36: 238, 1996.
31. Restifo, R. J., Ward, B. A., Scoutt, L. M., et al. Timing, magnitude, and utility of surgical delay in the TRAM flap: II. Clinical studies (see comments). *Plast. Reconstr. Surg.* 99: 1217, 1997.
32. Vinton, A. L., Traverso, L. W., and Jolly, P. C. Wound complications after modified radical mastectomy compared with tylectomy with axillary lymph node dissection. *Am. J. Surg.* 161: 584, 1991.
33. Zimmermann-Nielsen, E., Dahl, M. B., and Graversen, H. P. [Effects of tobacco smoking on the incidence of flap necrosis after mastectomy.] *Ugeskr. Laeger.* 159: 4974, 1997.
34. Takeishi, M., Shaw, W. W., Ahn, C. Y., and Borud, L. J. TRAM flaps in patients with abdominal scars (see comments). *Plast. Reconstr. Surg.* 99: 713, 1997.
35. Webster, R. C., Kazda, G., Hamdan, U. S., et al. Cigarette smoking and face lift: Conservative versus wide undermining. *Plast. Reconstr. Surg.* 77: 596, 1986.
36. Watterson, P. A., Bostwick, J., III, Hester, T. R., Jr., et al. TRAM flap anatomy correlated with a 10-year clinical experience with 556 patients (see comments). *Plast. Reconstr. Surg.* 95: 1185, 1995.
37. Kinsella, J. B., Rassekh, C. H., Wassmuth, Z. D., et al. Smoking increases facial skin flap complications. *Ann. Otol. Rhinol. Laryngol.* 108: 139, 1999.
38. Smith, J. B., and Fenske, N. A. Cutaneous manifestations and consequences of smoking (see comments). *J. Am. Acad. Dermatol.* 34: 717, 1996.
39. Jensen, J. A., Goodson, W. H., Hopf, H. W., and Hunt, T. K. Cigarette smoking decreases tissue oxygen. *Arch. Surg.* 126: 1131, 1991.
40. van Adrichem, L. N., Hovius, S. E., van Strik, R., and van der Meulen, J. C. Acute effects of cigarette smoking on microcirculation of the thumb. *Br. J. Plast. Surg.* 45: 9, 1992.