

# Autogenous Fat Grafting to the Breast and Gluteal Regions: Safety Profile Including Risks and Complications

Mustafa Chopan, M.D.  
Jared A. White, M.D.  
Lohrasb R. Sayadi, M.D.  
Patrick J. Buchanan, M.D.  
Adam J. Katz, M.D.

Gainesville, Fla.; and Irvine, Calif.

**Summary:** Given the widespread utility and therapeutic potential of autogenous fat grafting, plastic surgeons should be familiar with its safety profile and associated adverse events. This article provides a critical review of the literature and delineates risk factors associated with various complications when grafting to the breast and gluteal regions. The majority of adverse events are related to fat necrosis and require minimal diagnostic or therapeutic intervention. Larger graft volumes, as in cosmetic augmentation, are associated with higher incidences of fatty necrosis. The oncologic safety of fat grafting is supported by multiple clinical studies with thousands of breast cancer patients, albeit predominantly retrospective in nature. Although less frequent, serious complications include fat emboli during gluteal augmentation. Identification of associated risk factors and implementation of proper surgical techniques may minimize the occurrence of life-threatening complications. (*Plast. Reconstr. Surg.* 143: 1625, 2019.)

Autogenous fat grafting is increasingly used by plastic surgeons to accomplish various reconstructive and aesthetic objectives.<sup>1</sup> Their relative abundance, ease of harvest, minimal donor-site morbidity, and low immunogenicity make adipose grafts an ideal substitute filler for soft tissues. Historically, fat transplantation was a frustrating enterprise plagued by inconsistent results; however, its systematization in the 1990s repopularized the nearly abandoned practice.<sup>2</sup> The main issues surrounding fat grafting today are focused less on variable resorption and fibrous replacement of the graft but rather on the safety profile. In particular, there is lingering concern regarding fat grafting to the breasts in the context of oncologic reconstruction, and growing concern regarding grafting to the gluteal regions.<sup>3-5</sup> Potential associations with locoregional recurrence and reports of life-threatening complications have heightened the awareness of both professional societies and the public. Given the widespread utility of fat grafting and its therapeutic potential,

it would behoove plastic surgeons to familiarize themselves with its safety and associated adverse events. This article provides a critical review of the literature and delineates risk factors associated with various complications when grafting to the breast and gluteal regions.

## AUTOGENOUS FAT GRAFTING TO THE BREASTS

### Locoregional Recurrence and Cancer Risk

Fat grafting to the breasts is generally a safe procedure, with the majority of complications classified as Clavien-Dindo I (i.e., no endoscopic, surgical, radiologic, or major pharmacologic intervention required).<sup>3-8</sup> In the setting of breast reconstruction in particular, the issue of locoregional tumor recurrence in association with fat grafting may be most concerning to many. However, despite *in vitro* and *in vivo* studies suggesting the oncologic potential of autogenous fat grafts,<sup>9-19</sup> an association has not been confirmed in clinical settings. The basic science evidence, however, is often based on models not reflective of fat

*From the Department of Surgery, Division of Plastic and Reconstructive Surgery, University of Florida Health; and the Department of Plastic Surgery, University of California, Irvine.*

*Received for publication May 15, 2018; accepted November 16, 2018.*

*Copyright © 2019 by the American Society of Plastic Surgeons*

DOI: 10.1097/PRS.0000000000005617

**Disclosure:** None of the authors has a financial interest in any of the drugs, products, or devices mentioned in this article. There were no outside sources of funding.

grafting, but of isolated stem cells interacting with cancer cells. More accurate models of the interactions between fat graft and cancer cells are needed and do not suggest a higher rate of recurrence.<sup>20</sup> Rather, multiple retrospective case-control analyses and prospective case series have failed to show any elevation in recurrence risk.<sup>21–33</sup> These are well-organized investigations supported mostly by large study populations; however, they are limited by the inherent biases in their study design (e.g., retrospective, nonrandomized, nonblinded, and therefore susceptible to selection bias), inadequate follow-up (both timing and method of) to assess for tumor recurrence, and lack of clarity related to pertinent variables (e.g., management of positive margins after lumpectomy).

The most convincing studies include large comparative European and American cohorts that underwent either breast-conserving therapy or mastectomy with nearly 5-year follow-up periods. These studies did not reveal any significant increase in tumor recurrence after fat grafting.<sup>21,28</sup> In a subgroup analysis of in situ carcinoma, there was a significant association between tumor recurrence and fat transfer.<sup>28</sup> Although this finding was initially upheld in a subsequent comparative analysis,<sup>30</sup> longer term analysis showed that the control group recurrence rate caught up and the differences were no longer significant.<sup>22,34</sup> Aside from selection bias, other variables may have explained the originally observed risk and include the patient's age, modality of cancer treatment (often breast-conserving therapy in the setting of in situ disease), handling of margin status, and time to grafting.<sup>33</sup>

Breast conservation therapy is generally associated with a higher rate of local events. Nevertheless, a case-control study of 322 patients who received breast-conserving therapy and fat transfer (with equal number controls) with a 4.8-year follow-up revealed no increase in recurrence.<sup>22</sup> In prospective series of fat grafting after breast-conservation therapy, the local event rate per year is reported as either less than or equal to rates in the published literature.<sup>23,27</sup>

The American Society of Plastic Surgeons considers adipose grafts to have uncertain oncogenic potential in the setting of breast reconstruction.<sup>35</sup> However, as highlighted by this review, there is a significant body of evidence based on large retrospective, comparative studies that argue against an association. The continued monitoring and accrual of prospective data may further support its oncologic safety. Nevertheless, traditional factors associated with local

recurrence should be considered before adipose grafting. These characteristics include tumor size, nodal status, positive margins, histologic grade, and molecular (i.e., estrogen receptor, progesterone receptor, and human epidermal growth factor receptor 2) characteristics.<sup>36–38</sup> Although breast-conserving therapy has proven equal survival benefit in those undergoing a mastectomy, it is associated with an increased risk of local events.<sup>39,40</sup> Thus, breast-conserving therapy independently confers an elevated risk of recurrence along with other context-associated factors—such as younger age (younger than 35 years), premenopausal status, and peritumor vascular invasion—and should be considered by those who use fat grafting in this context. Irrespective of the modality of cancer treatment, proper adjuvant therapies should be pursued and completed before lipotransfer.

Similar to breast reconstruction, cosmetic augmentation with autogenous fat has not been associated with an increased likelihood of breast cancer beyond that of the average risk.<sup>41</sup> Practitioners are still cautioned when deciding to perform lipotransfer in healthy native tissue of patients with historical risk factors.

### **Fat Necrosis, Radiographic Abnormalities, and Other Complications**

The most common complication following lipotransfer is directly related to graft loss and manifests as variable forms of fat necrosis. The location and degree of liquefied fat, fibrosis, and calcifications ultimately determine its clinical significance and radiologic appearance. Fatty necrosis often occurs when grafted adipocytes incur too great a stress during the harvest and/or transfer processes, from direct damage related to tissue handling and/or inadequate diffusion of oxygen and nutrients before neovascularization. The Coleman technique is intended to optimize graft take by minimizing trauma and maximizing surface area-to-volume ratio with the recipient bed. Theoretically, techniques that adhere to these principles of fat grafting may allow for large-volume fat transfer with low risk of fat necrosis or other complications. However, proper handling and technique alone cannot overcome certain limitations, such as the compliance of the recipient bed. In large prospective series of cosmetic breast augmentation, the incidence of fat necrosis has been reported as high as 16 to 19 percent (based on imaging).<sup>42,43</sup> The wide range of fat necrosis reported in the literature may reflect a

difference in sensitivity of the methods used to detect such (i.e., magnetic resonance imaging versus ultrasound), the timing of such evaluations, and perhaps other variables. In reconstructive settings, usually in combination with implant or autologous flap transfer, the incidence of fat necrosis is reportedly lower.<sup>44</sup> The average volumes of autologous fat injected vary by at least 100 to 200 cc (with augmentation associated with larger volumes) and may contribute to the differential rates of fatty necrosis. Interestingly, oil cysts are more prevalent in reconstructive cases.<sup>45</sup> Perhaps adjuvant radiotherapy or chemotherapy modulates the immune response to fat necrosis and predisposes to cystic formation rather than fibrosis and calcification.

In 1987, autogenous grafting to the breast was condemned in part because of its perceived interference with breast cancer screening.<sup>46</sup> However, any surgical intervention to the breast is associated with a potential pathologic finding of fatty necrosis. These interventions include lumpectomy, reduction mammoplasty, and lipomodelling. Post-procedural radiographic abnormalities should be expected.<sup>47</sup> However, the majority of mammographic findings following lipotransfer can be classified as either Breast Imaging Reporting and Data System 1 or 2 (negative or benign findings, respectively).<sup>48,49</sup> On a meta-analysis of radiologic outcomes in 1979 patients who underwent breast reconstruction, nearly 12 percent of patients needed an interval mammogram, and over 2.5 percent needed a biopsy to diagnose the nature of a suspicious breast lump.<sup>6</sup> An alternative series of fat grafting to the breasts revealed a biopsy rate of 4.8 percent for radiographic and clinically suspicious lesions,<sup>25</sup> and all biopsy results were negative for malignancy. Infection, hematoma, seroma, induration, pneumothoraces, unsightly scars, and persistent pain are infrequently reported in the literature, likely reflecting their low incidence in clinical practice. The relevant risks and complications when fat grafting to the breasts are summarized in Table 1.

**Table 1. Autogenous Fat Grafting to the Breasts\***

	Reconstruction	Cosmetic Augmentation
Fat necrosis	4–4.6%	16–19%
Biopsy rate	2.5–4.8%	—
De novo cancer risk	No association	No association
Local recurrence/ distant metastases	No association	—

\*Risks and complications with regard to cosmetic augmentation and breast reconstruction.

## AUTOGENOUS FAT GRAFTING TO THE GLUTEAL REGION

Over the past decade, fat grafting to the gluteal region has seen a significant rise in popularity and demand among patients. Although the operation is performed more frequently, high-quality studies on the subject remain sparse. Many of the early reports on fat augmentation experimented with low volumes (30 to 210 ml) and do not document complication rates. Cardenas-Camarena et al. were one of the first groups to detail their complication rates with gluteal fat grafting, which ranged from minor complications (e.g., cellulitis, seroma, and tissue irregularities) to life-threatening fat embolism.<sup>50</sup> More recently, gluteal fat grafting has become the center of attention by plastic surgery task forces and experts because of reports of death by fat embolism during and following the procedure.<sup>4,51,52</sup> It should be emphasized that fat grafting to the gluteal region should be performed by experienced plastic surgeons who use risk-reduction techniques to minimize the chances for complications.

### Historical and Preoperative Factors

Gluteal augmentation with fat grafting is a cosmetic procedure often sought after by women in their early thirties.<sup>53,54</sup> However, gluteal augmentation may be beneficial for patients who have undergone massive weight loss surgery or suffer from deformities of the buttocks. As with all surgical procedures, patient selection is critical in reducing the risk for complications in gluteal fat grafting. First, discussion with a patient about their risk factors—including but not limited to a history of hematologic disorders, use of anticoagulants, and a family history of deep venous thrombosis and pulmonary embolism—is pertinent.<sup>55</sup> Physical examination of the lower extremities for the presence of varicose veins, which increases the risk of venous injury, should be performed.<sup>55</sup> Finally, a complaint of sciatic nerve symptoms should be considered a contraindication for the procedure, as the pain may get worse, and patients with these symptoms tend to have worse varicose veins in the region of the sciatic nerve distribution.<sup>56–58</sup>

The most common fat harvesting sites for the procedure are the lower extremities, followed by the back, hip, flanks, and abdominal areas.<sup>53</sup> To date, studies have failed to show a significant difference in adipose cell viability and graft take in relation to fat harvesting site.<sup>59,60</sup> To obtain fat for gluteal augmentation, most surgeons use machine-assisted liposuction and often process



the lipoaspirate by means of decantation.<sup>53</sup> After processing, a 3- to 4 mm rigid cannula is most often used for lipoinjection into the gluteal region subcutaneously and/or intramuscularly.<sup>53,55</sup> Large meta-analysis of the literature shows that the mean injection volume per buttock is  $402 \pm 179.2$  ml.<sup>53</sup>

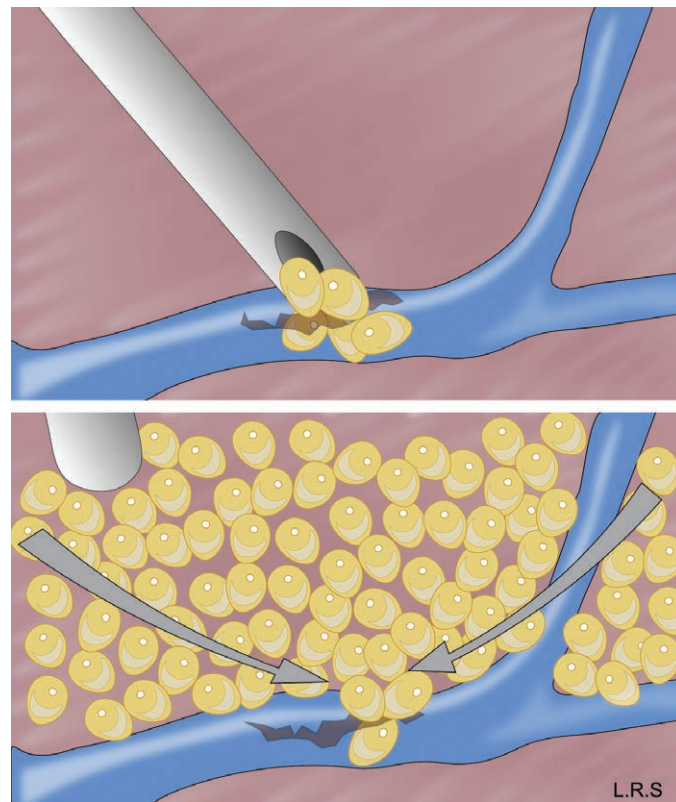
Overall, reported complication rates range from 7 (6.7 percent major and 0.32 percent minor) to 10.5 percent, with 95.5 percent of these being classified as minor complications.<sup>53,56,61</sup> The most common minor complications include seroma formation (2.4 to 3.5 percent), infection, erythema, pain, sciatica, contour irregularities, and fat necrosis.<sup>53,54,56,61,62</sup> Major complications for gluteal augmentation include fat embolism (0.12 percent), anemia, hypovolemia, and septic shock, all of which can be devastating. In addition, this risk of adverse events has been associated with increasing body mass index.<sup>63</sup> Studies show that the average body mass index for those seeking the operation is approximately  $23 \text{ kg/m}^2$ , with the peak incidence of major complications occurring in those with body mass indexes of 25 to  $30 \text{ kg/m}^2$ .<sup>53,63</sup>

### Venous Fat Embolism

Death because of fat embolism after gluteal augmentation has been a major area of concern and the subject of discussion among plastic surgeons. A survey conducted in 2015 by Cardenas-Camarena et al. of Mexican plastic surgeons uncovered 64 liposuction and 13 lipoinjection deaths caused by gluteal augmentation.<sup>64</sup> Among Colombian plastic surgeons, the same study found a total of nine cases of fat embolism.<sup>64</sup> In the United States, the Aesthetic Surgery Education and Research Foundation assembled a task force in 2017 to assess rates of fat embolism among board-certified plastic surgeons.<sup>4</sup> This study, which surveyed 692 surgeons across 198,857 gluteal fat grafting cases, found a total of 32 fatal (one of 6214 cases) and 103 nonfatal (one of 1931 cases) pulmonary fat embolisms, which were partially corroborated using public records.<sup>4</sup> However, it remains extremely difficult to accurately assess the rates of and practices involved with fat embolism because of the lack of a standardized database, lack of insurance claims relating to complications, and recall bias. It is likely that the overall numbers reported are actually quite different when taken into consideration with the low survey response rate and the fact that non-board-certified plastic surgeons are also performing the procedure. What is clear, however, is that death

by gluteal lipoinjection is a problem that must be addressed through high-quality research that delineates safe methods that are subsequently dispersed in an effective manner to those interested in performing the procedure.

The cause of fat embolism during gluteal augmentation procedures is the inadvertent entry of fat into the deep gluteal veins. The mechanistic details underlying this event are not definitively known, and this represents one of several areas ripe for further research. Some postulate that venous fat embolism results from inadvertent cannulation of a vein with subsequent intraluminal injection of fat. Others theorize that it can result from the “passive” syphoning of perivascular fat into a torn or lacerated vein that is characterized by a greater subatmospheric pressure relative to the surrounding extravascular space (Fig. 1). Either, both, or additional explanations may be correct, and the rigorous delineation of mechanisms underlying venous fat embolism has direct implications for specific methodologic recommendations that may reduce the risk of this fatal event. Many assume that the risk of fat embolism during gluteal augmentation can be significantly reduced by establishing specific guidelines and techniques. However, this itself is only a hypothesis at present, and many knowledge gaps and controversies currently exist. At present, there is little if any consensus among experts about various aspects of this operation, including what is the best/safest positioning of the patient, which size and type of cannulas to use, whether bolus injection or intermittent injection during withdrawal is most effective, which entry sites and angulation of cannulas are ideal, what is the upper safe limit of fat volume that can be injected during a single procedure, and whether intramuscular injection is safe or not. A review of the literature will reveal differing theories and recommendations, often in direct conflict with one another.<sup>4,51–53,55,63–69</sup> Although all of these published (and unpublished) recommendations are grounded in critical thinking and sound logic, they are nonetheless speculative in nature. Currently, there is a lack of high-level scientific evidence to support any particular recommendation. However, this may change based on current anatomical research being undertaken by the Multi-Society Gluteal Fat Grafting Task Force and others interested in this topic. Just recently the Multi-Society Gluteal Fat Grafting Task Force advocated for subcutaneous injection *only*, given recent reports of additional deaths and the finding that every patient that has died from venous fat embolism during the procedure was found to



**Fig. 1.** Postulated mechanisms for venous fat embolism during gluteal augmentation. (Above) Inadvertent cannulation of gluteal vein with subsequent intraluminal injection. (Below) Passive siphoning of perivascular fat into a torn or lacerated vein.

have fat in the gluteal muscle, along with injury to the gluteal veins. In no cases of death has fat been found only in the subcutaneous space. As higher level evidence emerges pertaining to gluteal fat grafting, one recommendation remains unanimous among all practitioners: it is paramount that surgeons who choose to perform this operation have a detailed knowledge of the anatomy of the gluteal region and a full understanding of the risks involved in performing the procedure. At the time of this writing, the Multi-Society Task Force, composed of representatives from the American Society of Plastic Surgeons, the American Society for Aesthetic Plastic Surgery, the International Society of Aesthetic Plastic Surgery, the International Federation for Adipose Therapeutics and Science, and the International Society of Plastic Regenerative Surgeons, is conducting detailed anatomical studies to elucidate technical aspects that may improve safety.

## DISCUSSION

Before the emergence of structural fat grafting, the clinical unpredictability of adipose

transplantation had plagued surgeons for nearly a century.<sup>70</sup> En bloc resection and transference of fatty tissue would invariably lead to cystic formation, as highlighted by Lyndon A. Peer's work in the 1950s. The advent of liposuction by Illouz and Fournier improved harvesting; however, the encouraging results by Sydney Coleman in the 1990s helped to codify the techniques that are often used in today's practice. The Coleman technique forms the basis of modern autogenous fat grafting,<sup>71</sup> and given its prevalence, patient historical factors, characteristics of the recipient bed, and the amount of fat injection largely influence risk and complications.

Autogenous fat grafting to the breasts is overall a safe procedure, with the majority of complications related to fat necrosis requiring minimal therapeutic or radiographic intervention. The oncologic safety of fat grafting is supported by multiple large, retrospective analyses. Although clinical studies argue against the tumorigenic potential of adipose grafts, further investigations with improved study designs may be required to convincingly assess for any associative, locoregional

tumor recurrence. The decreased fraction of adipose-derived stem cells in standard grafts (as opposed to those used in experimental studies) may account for the lack of any association.<sup>72</sup>

Furthermore, there are no studies available that guide the timing of lipotransfer in oncologic reconstruction. Most included studies allowed for at least 6 months to 1 year between breast cancer surgery and grafting. Generally, the risk of recurrence decreases as time from oncologic surgery increases; however, traditional factors of locoregional recurrence or distant metastases (i.e., positive margins or nodal status) will likely delay any grafting procedures because of the necessity for adjunctive cancer therapies. Also, early grafting is cautioned in the context of breast-conserving therapy because of the increased local event rate and potential for confounding foci of fatty necrosis. Other risk factors for recurrence after breast-conserving therapy, including younger age, premenopausal status, and tumor vascular invasion, should also be considered. In all patients considering cosmetic breast augmentation, with implants and/or autologous fat, a thorough and relevant history should be solicited for factors that may increase the likelihood of breast cancer above the average risk.

The amount of fat injected into a given recipient site is also associated with greater risk of fat necrosis, operative time, and other related complications. As such, the greater volumes of adipose graft needed to achieve augmentation as opposed to contouring may account for the differential rates of complications in the setting of reconstruction and cosmesis. Of note, the reported rates of fat necrosis following grafting to the breasts were based on imaging; thus, clinically detectable rates of fat necrosis may be less than indicated.

Gluteal augmentation by fat grafting is a cosmetic procedure with growing popularity. Unfortunately, the risk of complications following the procedure is 20 times higher than for other procedures performed at ambulatory surgery facilities.<sup>73</sup> In the future, research is needed to address and clarify pertinent anatomy, patient selection and positioning, injection cannula size and shape, continuous injection versus injection during cannula withdrawal only, safe zones/layers for injection, and more. There is also a need for new techniques and technologies such as those that enable the real-time visualization of a cannula tip in relation to tissue planes and structures. Table 2 lists summary statements regarding autogenous fat grafting to the breast and gluteal regions.

**Table 2. Summary Statements Regarding Autogenous Fat Grafting to the Breast and Gluteal Regions**

<b>Breasts</b>	Overall a safe procedure, with the majority of complications requiring little to no intervention The most common complication is fatty necrosis, which may be observed or imaged to clarify its nature The oncologic safety of fat grafting is supported by many large, retrospective analyses
<b>Gluteal</b>	Although gaining popularity, the risk of complications is much higher than for other ambulatory procedures Fat embolus is an area of major concern and is currently being investigated by the Multi-Society Task Force The Multi-Society Task Force advocates for subcutaneous injection only Surgeons who choose to perform this operation should have detailed knowledge of the anatomy of the gluteal region and a full understanding of the risks involved in performing the procedure Further research is needed to address and clarify pertinent anatomy, patient selection and positioning, cannula size and shape, continuous injection vs. injection during cannula withdrawal, and safe zones/layers for injection

## LIMITATIONS

Regarding published work on the topic of autogenous fat grafting to the breasts and gluteal regions, levels of evidence are generally low. The majority of published studies regarding the breasts were retrospectively or prospectively designed as case series. Aside from the technical deviations from the Coleman technique (harvesting, processing, and reinjection), there is yet considerable heterogeneity among included articles regarding indications, population characteristics, classification and reporting of complications, use of adjunctive therapies (e.g., external volume expansion device, platelet-rich plasma, cell-assisted lipotransfer), and follow-up periods. Even fewer and less rigorous studies are available regarding fat grafting to the gluteal regions, with the focus primarily on expert opinion and recommendations for risk-reduction techniques. Despite seeking the highest level of evidence for synthesis, this review is limited by the quality of available literature.

*Adam J. Katz, M.D.*

Division of Plastic and Reconstructive Surgery  
University of Florida College of Medicine  
P.O. Box 100138  
Gainesville, Fla. 32610  
adam.katz@surgery.ufl.edu

Twitter: @DrMChopan, @Ross\_Sayadi, @DrPJBuchanan

## REFERENCES

1. Kling RE, Mehrara BJ, Pusic AL, et al. Trends in autologous fat grafting to the breast: A national survey of the American Society of Plastic Surgeons. *Plast Reconstr Surg*. 2013;132:35–46.



2. Mazzola RF, Mazzola IC. History of fat grafting: From ram fat to stem cells. *Clin Plast Surg*. 2015;42:147–153.
3. Gutowski KA; ASPS Fat Graft Task Force. Current applications and safety of autologous fat grafts: A report of the ASPS fat graft task force. *Plast Reconstr Surg*. 2009;124:272–280.
4. Mofid MM, Teitelbaum S, Suissa D, et al. Report on mortality from gluteal fat rafting: Recommendations from the ASERF Task Force. *Aesthet Surg J*. 2017;37:796–806.
5. Multi-Society Gluteal Fat Grafting Task Force. Multi-Society Gluteal Fat Grafting Task Force issues safety advisory urging practitioners to reevaluate technique. Available at: [https://www.surgery.org/sites/default/files/Gluteal-Fat-Grafting-02-06-18\\_0.pdf](https://www.surgery.org/sites/default/files/Gluteal-Fat-Grafting-02-06-18_0.pdf). Accessed April 12, 2018.
6. Agha RA, Fowler AJ, Herlin C, Goodacre TE, Orgill DP. Use of autologous fat grafting for breast reconstruction: A systematic review with meta-analysis of oncological outcomes. *J Plast Reconstr Aesthet Surg*. 2015;68:143–161.
7. Claro F Jr, Figueiredo JC, Zampar AG, Pinto-Neto AM. Applicability and safety of autologous fat for reconstruction of the breast. *Br J Surg*. 2012;99:768–780.
8. Rosing JH, Wong G, Wong MS, Sahar D, Stevenson TR, Pu LL. Autologous fat grafting for primary breast augmentation: A systematic review. *Aesthetic Plast Surg*. 2011;35:882–890.
9. Eterno V, Zambelli A, Pavesi L, et al. Adipose-derived mesenchymal stem cells (ASCs) may favour breast cancer recurrence via HGF/c-Met signaling. *Oncotarget* 2014;5:613–633.
10. Iyengar P, Espina V, Williams TW, et al. Adipocyte-derived collagen VI affects early mammary tumor progression in vivo, demonstrating a critical interaction in the tumor/stroma microenvironment. *J Clin Invest*. 2005;115:1163–1176.
11. Ke CC, Liu RS, Suetsugu A, et al. In vivo fluorescence imaging reveals the promotion of mammary tumorigenesis by mesenchymal stromal cells. *PLoS One* 2013;8:e69658.
12. Kuhbier JW, Bucan V, Reimers K, et al. Observed changes in the morphology and phenotype of breast cancer cells in direct co-culture with adipose-derived stem cells. *Plast Reconstr Surg*. 2014;134:414–423.
13. Manabe Y, Toda S, Miyazaki K, Sugihara H. Mature adipocytes, but not preadipocytes, promote the growth of breast carcinoma cells in collagen gel matrix culture through cancer-stromal cell interactions. *J Pathol*. 2003;201:221–228.
14. Martin-Padura I, Gregato G, Marighetti P, et al. The white adipose tissue used in lipotransfer procedures is a rich reservoir of CD34+ progenitors able to promote cancer progression. *Cancer Res*. 2012;72:325–334.
15. Orecchioni S, Gregato G, Martin-Padura I, et al. Complementary populations of human adipose CD34+ progenitor cells promote growth, angiogenesis, and metastasis of breast cancer. *Cancer Res*. 2013;73:5880–5891.
16. Rowan BG, Gimble JM, Sheng M, et al. Human adipose tissue-derived stromal/stem cells promote migration and early metastasis of triple negative breast cancer xenografts. *PLoS One* 2014;9:e89595.
17. Schäffler A, Schölmerich J, Buechler C. Mechanisms of disease: Adipokines and breast cancer. Endocrine and paracrine mechanisms that connect adiposity and breast cancer. *Nat Clin Pract Endocrinol Metab*. 2007;3:345–354.
18. Sturtz LA, Deyarmin B, van Laar R, Yarina W, Shriver CD, Ellsworth RE. Gene expression differences in adipose tissue associated with breast tumorigenesis. *Adipocyte* 2014;3:107–114.
19. Zimmerlin L, Donnenberg AD, Rubin JP, Basse P, Landreneau RJ, Donnenberg VS. Regenerative therapy and cancer: In vitro and in vivo studies of the interaction between adipose-derived stem cells and breast cancer cells from clinical isolates. *Tissue Eng Part A* 2011;17:93–106.
20. Tsuji W, Valentin JE, Marra KG, Donnenberg AD, Donnenberg VS, Rubin JP. An animal model of local breast cancer recurrence in the setting of autologous fat grafting for breast reconstruction. *Stem Cells Transl Med*. 2018;7:125–134.
21. Kronowitz SJ, Mandujano CC, Liu J, et al. Lipofilling of the breast does not increase the risk of recurrence of breast cancer: A matched controlled study. *Plast Reconstr Surg*. 2016;137:385–393.
22. Petit JY, Maisonneuve P, Rotmensz N, Bertolini F, Rietjens M. Fat grafting after invasive breast cancer: A matched case-control study. *Plast Reconstr Surg*. 2017;139:1292–1296.
23. Brenelli F, Rietjens M, De Lorenzi F, et al. Oncological safety of autologous fat grafting after breast conservative treatment: A prospective evaluation. *Breast J*. 2014;20:159–165.
24. Cohen O, Lam G, Karp N, Choi M. Determining the oncologic safety of autologous fat grafting as a reconstructive modality: An institutional review of breast cancer recurrence rates and surgical outcomes. *Plast Reconstr Surg*. 2017;140:382e–392e.
25. Kaoutzanis C, Xin M, Ballard TN, et al. Autologous fat grafting after breast reconstruction in postmastectomy patients: Complications, biopsy rates, and locoregional cancer recurrence rates. *Ann Plast Surg*. 2016;76:270–275.
26. Myckatyn TM, Wagner IJ, Mehrara BJ, et al. Cancer risk after fat transfer: A multicenter case-cohort study. *Plast Reconstr Surg*. 2017;139:11–18.
27. Perez-Cano R, Vranckx JJ, Lasso JM, et al. Prospective trial of adipose-derived regenerative cell (ADRC)-enriched fat grafting for partial mastectomy defects: The RESTORE-2 trial. *Eur J Surg Oncol*. 2012;38:382–389.
28. Petit JY, Botteri E, Lohsiriwat V, et al. Locoregional recurrence risk after lipofilling in breast cancer patients. *Ann Oncol*. 2012;23:582–588.
29. Petit JY, Lohsiriwat V, Clough KB, et al. The oncologic outcome and immediate surgical complications of lipofilling in breast cancer patients: A multicenter study. Milan-Paris-Lyon experience of 646 lipofilling procedures. *Plast Reconstr Surg*. 2011;128:341–346.
30. Petit JY, Rietjens M, Botteri E, et al. Evaluation of fat grafting safety in patients with intraepithelial neoplasia: A matched-cohort study. *Ann Oncol*. 2013;24:1479–1484.
31. Riggio E, Bordoni D, Nava MB. Oncologic surveillance of breast cancer patients after lipofilling. *Aesthetic Plast Surg*. 2013;37:728–735.
32. Seth AK, Hirsch EM, Kim JY, Fine NA. Long-term outcomes following fat grafting in prosthetic breast reconstruction: A comparative analysis. *Plast Reconstr Surg*. 2012;130:984–990.
33. Gale KL, Rakha EA, Ball G, Tan VK, McCulley SJ, Macmillan RD. A case-controlled study of the oncologic safety of fat grafting. *Plast Reconstr Surg*. 2015;135:1263–1275.
34. Petit JY, Maisonneuve P, Rotmensz N, et al. Safety of lipofilling in patients with breast cancer. *Clin Plast Surg*. 2015;42:339–344, viii.
35. American Society of Plastic Surgeons. Post-mastectomy fat graft/fat transfer ASPS guiding principles. Available at: <https://www.plasticsurgery.org/Documents/Health-Policy/Principles/principle-2015-post-mastectomy-fat-grafting.pdf>. Accessed January 22, 2018.
36. Lowery AJ, Kell MR, Glynn RW, Kerin MJ, Sweeney KJ. Locoregional recurrence after breast cancer surgery: A systematic review by receptor phenotype. *Breast Cancer Res Treat*. 2012;133:831–841.
37. Neri A, Marrelli D, Rossi S, et al. Breast cancer local recurrence: Risk factors and prognostic relevance of early time to recurrence. *World J Surg*. 2007;31:36–45.

38. Voogd AC, Nielsen M, Peterse JL, et al.; Danish Breast Cancer Cooperative Group; Breast Cancer Cooperative Group of the European Organization for Research and Treatment of Cancer. Differences in risk factors for local and distant recurrence after breast-conserving therapy or mastectomy for stage I and II breast cancer: Pooled results of two large European randomized trials. *J Clin Oncol*. 2001;19:1688–1697.
39. Fisher B, Anderson S, Bryant J, et al. Twenty-year follow-up of a randomized trial comparing total mastectomy, lumpectomy, and lumpectomy plus irradiation for the treatment of invasive breast cancer. *N Engl J Med*. 2002;347:1233–1241.
40. Veronesi U, Cascinelli N, Mariani L, et al. Twenty-year follow-up of a randomized study comparing breast-conserving surgery with radical mastectomy for early breast cancer. *N Engl J Med*. 2002;347:1227–1232.
41. Groen JW, Negenborn VL, Twisk JW, Ket JC, Mullender MG, Smit JM. Autologous fat grafting in cosmetic breast augmentation: A systematic review on radiological safety, complications, volume retention, and patient/surgeon satisfaction. *Aesthet Surg J*. 2016;36:993–1007.
42. Khouri RK, Eisenmann-Klein M, Cardoso E, et al. Brava and autologous fat transfer is a safe and effective breast augmentation alternative: Results of a 6-year, 81-patient, prospective multicenter study. *Plast Reconstr Surg*. 2012;129:1173–1187.
43. Khouri RK, Khouri RK Jr, Rigotti G, et al. Aesthetic applications of Brava-assisted megavolume fat grafting to the breasts: A 9-year, 476-patient, multicenter experience. *Plast Reconstr Surg*. 2014;133:796–807; discussion 808–809.
44. Missana MC, Laurent I, Barreau L, Balleyguier C. Autologous fat transfer in reconstructive breast surgery: Indications, technique and results. *Eur J Surg Oncol*. 2007;33:685–690.
45. Groen JW, Negenborn VL, Twisk DJWR, et al. Autologous fat grafting in onco-plastic breast reconstruction: A systematic review on oncological and radiological safety, complications, volume retention and patient/surgeon satisfaction. *J Plast Reconstr Aesthet Surg*. 2016;69:742–764.
46. Report on autologous fat transplantation. ASPRS Ad-Hoc Committee on New Procedures, September 30, 1987. *Plast Surg Nurs*. 1987;7:140–141.
47. Spear SL, Pittman T. A prospective study on lipoaugmentation of the breast. *Aesthet Surg J*. 2014;34:400–408.
48. Illouz YG, Sterodimas A. Autologous fat transplantation to the breast: A personal technique with 25 years of experience. *Aesthetic Plast Surg*. 2009;33:706–715.
49. Rubin JP, Coon D, Zuley M, et al. Mammographic changes after fat transfer to the breast compared with changes after breast reduction: A blinded study. *Plast Reconstr Surg*. 2012;129:1029–1038.
50. Cardenas-Camarena L, Lacouture AM, Tobar-Losada A. Combined gluteoplasty: Liposuction and lipoinjection. *Plast Reconstr Surg*. 1999;104:1524–1531; discussion 1532–1533.
51. Pronovost PJ, Ishii LE. Commentary on: Report on mortality from gluteal fat grafting: Recommendations from the ASERF task force. *Aesthet Surg J*. 2017;37:811–813.
52. Wall S Jr, Del Vecchio D. Commentary on: Report on mortality from gluteal fat grafting: Recommendations from the ASERF task force. *Aesthet Surg J*. 2017;37:807–810.
53. Condé-Green A, Kotamarti V, Nini KT, et al. Fat grafting for gluteal augmentation: A systematic review of the literature and meta-analysis. *Plast Reconstr Surg*. 2016;138:437e–446e.
54. Rosique RG, Rosique MJ, De Moraes CG. Gluteoplasty with autologous fat tissue: Experience with 106 consecutive cases. *Plast Reconstr Surg*. 2015;135:1381–1389.
55. Villanueva NL, Del Vecchio DA, Afrooz PN, Carboy JA, Rohrich RJ. Staying safe during gluteal fat transplantation. *Plast Reconstr Surg*. 2018;141:79–86.
56. Sinno S, Chang JB, Brownstone ND, Saadeh PB, Wall S Jr. Determining the safety and efficacy of gluteal augmentation: A systematic review of outcomes and complications. *Plast Reconstr Surg*. 2016;137:1151–1156.
57. Cardenas-Mejia A, Martínez JR, León D, Taylor JA, Gutierrez-Gomez C. Bilateral sciatic nerve axonotmesis after gluteal lipoaugmentation. *Ann Plast Surg*. 2009;63:366–368.
58. Astarita DC, Scheinin LA, Sathyavagiswaran L. Fat transfer and fatal macroembolization. *J Forensic Sci*. 2015;60:509–510.
59. Li K, Gao J, Zhang Z, et al. Selection of donor site for fat grafting and cell isolation. *Aesthetic Plast Surg*. 2013;37:153–158.
60. Ullmann Y, Shoshani O, Fodor A, et al. Searching for the favorable donor site for fat injection: In vivo study using the nude mice model. *Dermatol Surg*. 2005;31:1304–1307.
61. Oranges CM, Tremp M, di Summa PG, et al. Gluteal augmentation techniques: A comprehensive literature review. *Aesthet Surg J*. 2017;37:560–569.
62. Roberts TL III, Toledo LS, Badin AZ. Augmentation of the buttocks by micro fat grafting. *Aesthet Surg J*. 2001;21:311–319.
63. Bruner TW, Roberts TL III, Nguyen K. Complications of buttocks augmentation: Diagnosis, management, and prevention. *Clin Plast Surg*. 2006;33:449–466.
64. Cárdenas-Camarena L, Bayer JE, Aguirre-Serrano H, Cuenca-Pardo J. Deaths caused by gluteal lipoinjection: What are we doing wrong? *Plast Reconstr Surg*. 2015;136:58–66.
65. Del Vecchio D, Wall S Jr. Expansion vibration lipofilling: A new technique in large-volume fat transplantation. *Plast Reconstr Surg*. 2018;141:639e–649e.
66. Mendieta C, Stuzin JM. Gluteal augmentation and enhancement of the female silhouette: Analysis and technique. *Plast Reconstr Surg*. 2018;141:306–311.
67. Ramos-Gallardo G, Orozco-Rentería D, Medina-Zamora P, et al. Prevention of fat embolism in fat injection for gluteal augmentation, anatomic study in fresh cadavers. *J Invest Surg*. 2018;31:292–297.
68. Rosique RG, Rosique MJ. Deaths caused by gluteal lipoinjection: What are we doing wrong? *Plast Reconstr Surg*. 2016;137:641e–642e.
69. Toledo LS. Gluteal augmentation with fat grafting: The Brazilian buttock technique—30 years' experience. *Clin Plast Surg*. 2015;42:253–261.
70. Santoni-Rugui P, Sykes PJ. *A History of Plastic Surgery*. Berlin: Springer; 2007.
71. Coleman SR. The Coleman technique. In: Coleman SR, Mazzola RF, Pu LLQ, eds. *Fat Injection: From Filling to Regeneration*. 2nd ed. New York: Thieme; 2018:86–146.
72. Charvet HJ, Orbay H, Wong MS, Sahar DE. The oncologic safety of breast fat grafting and contradictions between basic science and clinical studies: A systematic review of the recent literature. *Ann Plast Surg*. 2015;75:471–479.
73. Keyes GR, Singer R, Iverson RE, et al. Mortality in outpatient surgery. *Plast Reconstr Surg*. 2008;122:245–250; discussion 251–253.