Critical Differences between Microscopic (MIFE) and Macroscopic (MAFE) Fat Embolism during Liposuction and Gluteal Lipoinjection

Lázaro Cárdenas-Camarena, M.D.
Héctor Durán, M.D.
José Antonio Robles-Cervantes, M.D., Ms.C., Ph.D.
Jorge Enrique Bayter-Marin, M.D.

Zapopan, Jalisco, and Mérida, Yucatán, México; and Bucaramanga, Colombia

PATIENT SAFETY

Background: Liposuction and gluteal lipoinjection are two of the most frequent surgical procedures in body contouring surgery, and two of the most important complications are microscopic (MIFE) and macroscopic (MAFE) fat embolism. Despite a high index of morbidity and mortality, few reports exist about these complications, and although they have the same causal agent, their etiopathogenesis, clinical evolution, treatment, prognosis, and prevention are totally different. Therefore, the authors performed a comprehensive review of the literature to exhaustively analyze both pathologic conditions and present the differences between them.
Methods: A detailed search was carried out in PubMed of studies on humans from 1946 to March of 2017 in any language and including the keywords microscopic fat embolism and macroscopic fat embolism with either liposuction or gluteal lipoinjection. The articles found were selected according to the search criteria and were analyzed to provide the final data and recommendations.
Results: Of the 1245 and 26 articles that were found on complications related to liposuction and gluteal lipoinjection, respectively, only 41 on liposuction and microscopic fat embolism and seven on gluteal lipoinjection and microscopic fat embolism met the specific criteria for inclusion in the analysis. Only two articles on liposuction and two on gluteal lipoinjection referred to macroscopic fat embolism as a complication.
Conclusion: Although microscopic fat embolism and macroscopic fat embolism are pathologic conditions with high morbidity and mortality rates in association with liposuction and gluteal lipoinjection, few reports about them exist; therefore, the authors made recommendations based on this study for their diagnosis, prevention, and treatment. (*Plast. Reconstr. Surg.* 141: 880, 2018.)

Body contouring surgery is performed frequently worldwide,[1] and the combination of liposuction with gluteal lipoinjection is currently the most requested and most performed body-contouring procedure.[2–4] However, this operation can result in complications caused by the manipulation of fatty tissue, such as a fat embolism.[5] Although a fat embolism caused by liposuction or lipoinjection has not been reported previously as a significant complication,[6,7] actually one of the most severe problems with these operations at present is the entry of fat into the bloodstream, which can cause a fat embolism syndrome. However, the presence of fat in the bloodstream can cause a fat embolism in two different ways, as a microscopic fat embolism (MIFE) or as a macroscopic fat embolism (MAFE).[8] Few published articles mention these problems as consequences of these procedures. Similarly, confusion exists in the descriptions of both terms because, although the causal agent is the same in both pathologic conditions (i.e., the

From Innovare Cirugía Plástica Especializada, the Divisions of Plastic Surgery and Internal Medicine, Jalisco Institute of Reconstructive Surgery "Dr. José Guerrerosantos"; the Jalisco College of Plastic, Esthetic and Reconstructive Surgery; private practice; and Clínica "El Pinar."
Received for publication May 4, 2017; accepted October 18, 2017.

DOI: 10.1097/PRS.0000000000004219

Disclosure: *The authors have no conflict of interest to declare in relation to the content of this article.*

By reading this article, you are entitled to claim one (1) hour of Category 2 Patient Safety Credit. ASPS members can claim this credit by logging in to PlasticSurgery.org Dashboard, clicking "Submit CME," and completing the form.

presence of fat in the bloodstream), the etiopathogenesis, clinical presentation, evolution, treatment, and prognosis of each condition are completely different. Moreover, no study to date has clearly identified the differences between these problems or how to prevent them.[8] Therefore, we performed a broad review of the medical literature to identify reports describing MIFE and MAFE as complications of liposuction and gluteal lipoinjection, and we analyzed the differences between the two pathologic conditions, including their prognosis, diagnosis, and management to establish possible preventative measures.

PATIENTS AND METHODS

We analyzed publications on fat embolism syndrome, MIFE, and MAFE associated with both liposuction and gluteal lipoinjection. Because of the etiopathogenesis and clinical evolution, we can consider fat embolism syndrome as microscopic fat embolism; thus, a literature search of the PubMed database (U.S. National Library of Medicine) was performed for studies from 1946 through March 30, 2017, by searching for specific words and phrases in any part of the article. Articles in any language were included, and studies on liposuction and gluteal lipoinjection were investigated. In searching for studies on liposuction, the following seven terms were used: "liposuction," "liposuction AND complications," "liposuction AND complications AND fat embolism," "liposuction AND complications AND fat embolism syndrome," "liposuction AND macroscopic fat embolism," "liposuction AND fat embolism," and "liposuction AND fat embolism syndrome."

For gluteal lipoinjection, the following terms were investigated: "gluteal AND fat grafting," "gluteal AND lipoinjection," "gluteal AND fat grafting AND complications," "gluteal AND lipoinjection AND complications," "gluteal AND fat grafting AND fat embolism syndrome," "gluteal AND lipoinjection AND fat embolism syndrome," and "gluteal AND lipoinjection AND macroscopic fat embolism." We also searched the same phrases but replaced the word "gluteal" with "buttocks." Subsequently, the search for all terms was narrowed using filters to obtain results only for humans and then only for human-related review articles about each topic.

The quantity and the content of the results of the phrase searches were analyzed. The results were refined to determine the final inclusion of articles, and only articles containing fat embolism syndrome/MIFE and MAFE as complications were included. The included articles were analyzed to determine the specific characteristics of both abnormalities, including the etiopathogenesis, causes, clinical features, evolution, diagnosis, prognosis, and treatment of each complication. The differences between fat embolism syndrome/MIFE and MAFE are also described.

RESULTS

Sixty-nine results were obtained for the search for phrases using the terms "liposuction AND fat embolism syndrome" from 1946 through March 15, 2017. The terms "fat embolism" and "fat embolism syndrome" returned identical results. This finding indicates that both terms are used without any differentiation; therefore, search results for "fat embolism" were eliminated, and only those for "fat embolism syndrome" were retained. Because the terms "gluteal" and "buttocks" returned very similar results, we chose to use only the phrases with the word "gluteal." One specific review article about gluteal lipoinjection complications was found. Three articles about gluteal lipoinjection indicated fat embolism syndrome/MIFE as a complication, and only two articles associated MAFE with gluteal lipoinjection.

We identified 54 articles related to humans with the search phrase "liposuction AND fat embolism syndrome," of which 40 included the fat embolism syndrome abnormality. These 40 articles were included and analyzed in this study. Within these articles, 27 were included on the basis of searching "liposuction AND complications AND fat embolism," and three were included on the basis of searching "liposuction AND macroscopic fat embolism." Seven articles related to humans identified from the search phrase "gluteal AND fat grafting AND fat embolism syndrome" were also included in the analysis. These included the articles identified with the search phrases "gluteal AND lipoinjection AND fat embolism syndrome" and the two articles found searching for "gluteal AND lipoinjection AND macroscopic fat embolism." Letters or comments were excluded from the list of original articles analyzed because they did not contribute more cases.

The results of the words analyzed in searches of articles about liposuction and gluteal lipoinjection and the number of articles found are shown in Tables 1 and 2, respectively. Works reporting cases of fat embolism in humans are shown in Table 3.

DISCUSSION

With the advent of new surgical techniques and the modification of existing techniques, pathologic

Table 1. Terms Used and Number of Articles Found for Liposuction and Fat Embolism

Terms	General	In Humans	Reviews in Humans
Liposuction	4326	3830	449
Liposuction AND complications	1349	1245	171
Liposuction AND fat embolism syndrome	69	54	7
Liposuction AND complications AND fat embolism syndrome	31	27	3
Liposuction AND macroscopic fat embolism	4	3	0

Table 2. Terms Used and Number of Articles Found for Gluteal Lipoinjection and Fat Embolism

Terms	General	In Humans	Reviews in Humans
Gluteal AND fat grafting	61	55	4
Gluteal AND lipoinjection	15	13	1*
Gluteal AND fat grafting AND complications	29	26	1*
Gluteal AND lipoinjection AND complications	7	6	1*
Gluteal AND fat grafting AND fat embolism syndrome	8	7†	0
Gluteal AND lipoinjection AND fat embolism syndrome	3	5†	0
Gluteal AND lipoinjection AND macroscopic fat embolism	2	2‡	0

*It was the same article.
†Two of these articles were comments of the original articles.
‡These articles are two of the five articles referred to under "gluteal AND lipoinjection AND fat embolism syndrome."

Table 3. Works Reporting Cases of Fat Embolism in Humans

Reference	Cases Associated with Liposuction without Gluteal Augmentation	Cases Associated with Liposuction with Gluteal Augmentation	MIFE OR MAFE*
Christman, 1986[44]	1	0	MIFE
Ross and Johnson, 1988[28]	1	0	MIFE
Teimourian and Rogers, 1989[6]	4	0	MIFE
Abbes and Bourgeon, 1989[45]	1	0	MIFE
Laub and Laub, 1990[48]	1	0	MIFE
Boezaart et al., 1990[46]	1	0	MAFE
Fourme et al., 1998[51]	1	0	MAFE
Cárdenas-Camarena et al., 1999[2]	0	1	MIFE
Cárdenas-Camarena et al., 2003†[3]	0	2	MIFE
Cárdenas-Camarena et al., 2011‡[4]	0	2	MIFE
Cohen et al., 2014[33]	1	0	MIFE
Cárdenas-Camarena et al., 2015[12]	0	9	MAFE

MIFE, microscopic fat embolism; MAFE, macroscopic fat embolism.
*The denomination of MIFE or MAFE was determined according to the clinical evolution that is reported in each publication. We consider MAFE to be present if the symptoms began during surgery or during the first 24 hr, and MIFE if they began 24 hr suddenly after surgery.
†One of these patients was the same one in a previous report in 1999.
‡These two patients were reported in previous articles (1999–2011).

conditions and complications that previously did not exist or were poorly reported began to appear. Liposuction was popularized as a standardized surgical procedure in the 1980s by Illouz[9] and Fournier and Otteni.[10] Since that time, and for more than 30 years according to the results of this study, approximately 1250 articles have reported complications associated with liposuction, of which fewer than 5 percent mention fat embolism syndrome. The same phenomenon occurs with macroscopic fat embolism associated with gluteal lipoinjection, where only five of slightly more than 50 surgical procedure articles mention fat embolism syndrome, and of these five articles, three are by the same author. Thus, only three authors worldwide have reported this problem associated with gluteal lipoinjection. In a report of patients with lipoabdominoplasty, two of 173 patients had a pulmonary embolism.[11] In the case of gluteal lipoinjection, fat enters the bloodstream because of a lesion in a vein secondary to deep intramuscular lipoinjection, as has been recently reported[12,13]; however, this situation does not explain all of the cases. According to Cárdenas-Camarena et al.,[12] the fat entry into the bloodstream can occur in two ways and generates two pathologic conditions: microscopically or macroscopically. More accurate terms for fat embolism syndrome, to avoid confusion between both pathologic conditions, are MIFE and MAFE. We consider that when fat enters microscopically (microscopic fat

embolism), it produces the so-called fat embolism syndrome, whereas when it enters macroscopically, it produces the direct occlusion of blood vessels and causes a macroscopic fat embolism,[14] as shown by reports presenting this condition.[12] Macroscopic fat embolism is clinically very similar to pulmonary thromboembolism secondary to a blood clot. Both microscopic fat embolism and macroscopic fat embolism have the same causal agent, which is the introduction and presence of fat in the bloodstream. However, other than this similarity, the two processes are completely different. All experimental animal models used to produce fat embolism syndrome are based on injecting a mixture of different oils consisting of liquid fat, which is very irritating. This phenomenon may explain why fat embolism syndrome is likely to occur when significant resorption of this fluid occurs during surgery. In contrast, adipocytes absorbed in a macroscopic form occlude the pulmonary circulation and generate a macroscopic fat embolism before producing any effects associated with microscopic fat embolism.[15,16]

Curiously, the answer to preventing microscopic fat embolism could lie in the liposuction bottles that we use during liposuction. Three main fractions can be observed after the fat content has been decanted: liquid mixed with blood at the bottom, adipocytes and fat globules in the middle, and liquid fat resulting from the lysis of adipocytes at the top. This liquid fat is the most irritating part of the material collected by means of liposuction and is the most harmful if it enters the bloodstream.

Etiopathogenesis of Microscopic Fat Embolism

Fat particles that block pulmonary capillaries are 10 to 40 μm in diameter.[17] These particles can then be hydrolyzed by lipases produced by pneumocytes. According to different theories of the etiopathogenesis of microscopic fat embolism, this hydrolysis forms free fatty acids that are toxic to endothelial and alveolar cells, resulting in hemorrhaging and alveolar edema and producing the symptomatology presented by patients in the postoperative period between 48 and 72 hours.[7,18,19] Fat embolism was initially described in traumatology as a consequence of fractures in long bones,[20] whereas its description or presence in cosmetic surgery appeared as a complication with the advent of liposuction, with the first reports in the late 1980s.[21–23] Some authors have suggested that fat droplets are observed frequently in the blood of healthy individuals without clinical evidence of microscopic fat embolism.[24,25] Although fat enters the bloodstream in all patients, why and how this problem is present in some patients and not in others is unclear.[26] We do know that the problem is aggravated by the presence of dehydration in the patient during the immediate postoperative period, which causes a higher concentration of free fatty acids in the bloodstream,[27] a factor that has been mentioned as a trigger of microscopic fat embolism through irritation of the endothelia of capillaries and small vessels.[28,29] This irritation produces the signs and symptoms of microscopic fat embolism after surgery, mainly in the central nervous system, lungs, and skin.[30,31] The patient may present alterations in behavior and consciousness, fever, dyspnea, and petechiae.[24] These signs and symptoms are described in the criteria of Gurd and Wilson for fat embolism syndrome,[30,31] with at least one major criterion and four minor criteria required to establish a diagnosis of microscopic fat embolism.[31] Unfortunately, the clinical presentation often does not follow the classic form we may expect and may even be very subtle in some cases. Because the classic triad of symptoms occurs in less than 2 percent of cases,[32] clinical analysis remains the gold standard for establishing a diagnosis of microscopic fat embolism.[33,34] Lindegue also proposed criteria based on respiratory alterations and gas parameters.[8] The diagnosis must be established early with assistance from paraclinical analyses such as pulse oximetry, a urine test to detect fat, serum lipase and phospholipase,[7] gasometry, electrocardiography, echocardiography, and a bronchoalveolar lavage to search for the presence of alveolar fat globules in macrophages.[8,35,36] Areas of consolidation, ground-glass opacity, micronodules smaller than 10 mm, interstitial or alveolar hemorrhaging, edema, or pneumonitis can be found by computed axial tomography.[14,21,22,37–39] The successful management of these patients includes the rapid initiation of treatment because early treatment considerably improves disease progression and patient prognosis. Microscopic fat embolism has a 10 percent mortality rate when early treatment is established; conversely, the mortality rate can rise to 35 percent following late treatment.[27] Treatment requires regular support measures using adequate fluid resuscitation therapy, and up to 44 percent of patients need a period of mechanical ventilation. Albumin is frequently indicated to not only maintain the volume but also to bind free fatty acids and theoretically reduce inflammation. However, albumin must be administered with caution because it can also accumulate in the interstitial lung compartment and cause respiratory failure.[24,34] Low-molecular-weight dextran may reduce platelet aggregation and prevent thrombocytopenia and cell aggregation. Other authors have considered the use of heparin or

corticosteroids, but these treatments have not been shown to reduce morbidity and mortality rates. The use of prophylactic methylprednisolone administered at doses ranging from 9 to 90 mg/kg for 2 to 3 days may have beneficial effects, although this treatment does not decrease mortality rates.[17,27] Another option is the use of ciclesonide, which is an inhaled steroid that has been shown in a nonrandomized study to be a safe and effective prophylactic therapy for posttraumatic microscopic fat embolism[40] and to help prevent severe hypoxia.[8,41] Alcohol reduces serum lipase activity, and patients with fractures saturated in alcohol have a lower incidence of microscopic fat embolism. Reports have suggested that this treatment should be performed with a 5% alcohol bolus, although this approach has not been accepted.[24] However, despite all of these therapeutic options, microscopic fat embolism mortality remains at 10 to 30 percent.[32,34,37,42]

Etiopathogenesis of Macroscopic Fat Embolism

Macroscopic fat embolism is a pathologic condition with a recent inclusion in the medical literature of plastic surgery,[12,13] and its presentation is acute cardiorespiratory failure. It is important to mention that because macroscopic fat embolism is new in the medical literature, much of what is mentioned here is based on clinical presentation and in correlation with other abnormalities, such as pulmonary thromboembolism. Because of the sudden onset of the clinical condition and the findings reported in previous studies,[12] we consider that the problems associated with macroscopic fat embolism are totally attributable to a mechanical event and that the prognosis is very poor, because these types of problems are usually fatal. Prevention is best for macroscopic fat embolism, and avoiding the injection of fat into the deep muscular planes has been reported to be the most important preventive measure.[12] Veins are located deep in the gluteal musculature, below the gluteus maximus and medius. These vessels emerge above and below the pyramidal muscle, where the inferior gluteal vessels are next to the sciatic nerve (Fig. 1). Therefore, the main recommendation is to avoid injury of the deep gluteal vessels, and to

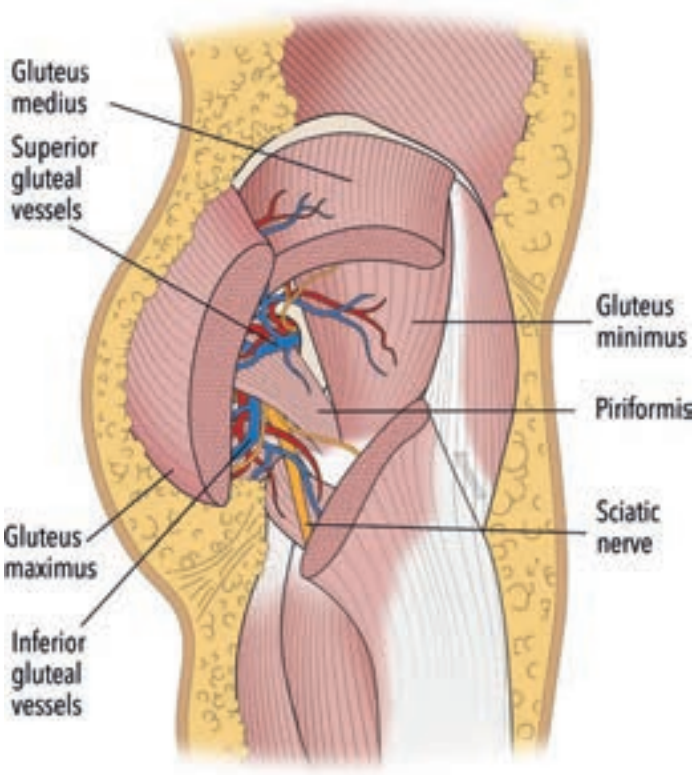

Fig. 1. Anatomy of the gluteal region. The gluteus major vessels are located below the gluteus maximus and gluteus medius muscles, emerging above and below the pyramidal muscle. The lower gluteal vessels emerge along with the sciatic nerve, a very important structure in this region.

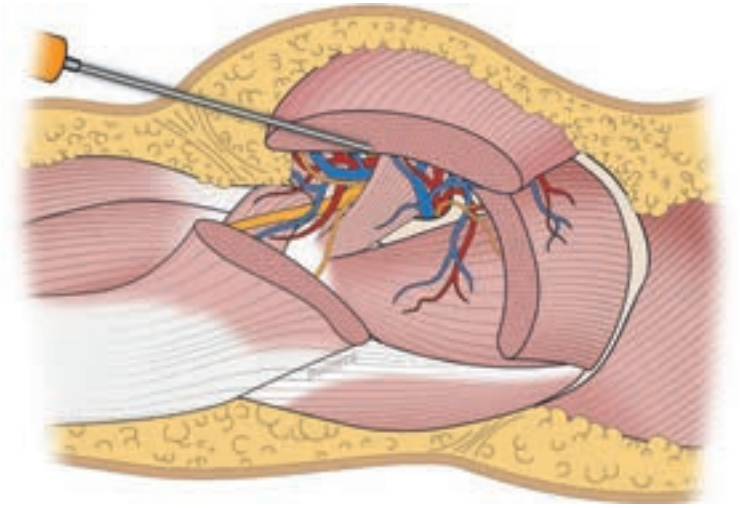

Fig. 2. Lipoinjection through the infragluteal crease is one of the most dangerous approaches with regard to injuring the gluteal vessels.

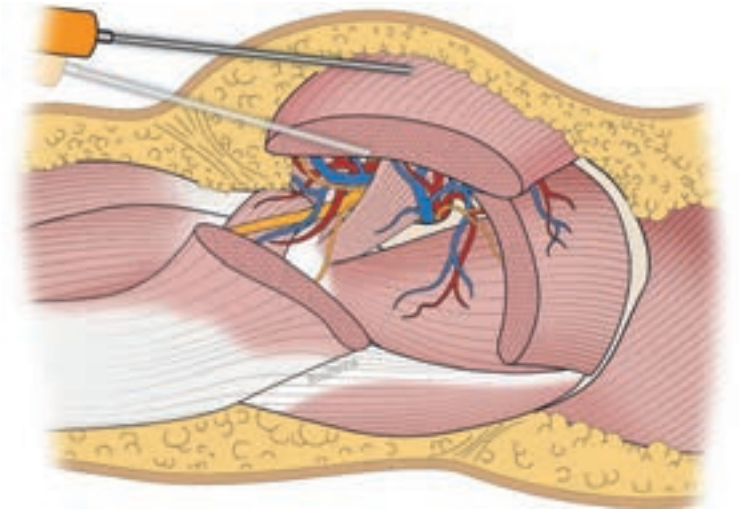

Fig. 3. The cannula should be directed to superficial planes, keeping it parallel to the thigh and thus avoiding going too deep.

achieve this, we suggest maintaining the cannula in a superficial plane, as the infragluteal approach is riskier (Figs. 2 and 3). Taking this precaution, we also suggest injecting the fat into the subcutaneous planes or in a very superficial muscular plane (Figs. 4 and 5). If the cannula is angled downward, it will move deeper, and the risk of gluteal vessel injury increases greatly (Fig. 6). Because the gluteal venous system maintains a constant negative pressure, any laceration of gluteal veins allows fat to be absorbed into the bloodstream; thus, a complete cut of a vein or the direct injection of the fat is not necessary for the problem to occur[12] (Fig. 7). In contrast to microscopic fat embolism, the main feature of macroscopic fat embolism is that it starts almost immediately at the time of fat injection. After entering the bloodstream, the fat embolism obstructs large veins, the heart, or pulmonary capillaries, as shown previously.[12] Clots of fat 1 to 8 cm in diameter have been detected in transesophageal echocardiograms.[24] In adults, a lethal intravenous injection of fat can range from 15 to 50 ml.[16,17] The diagnosis must be made clinically because of the rapidity and severity of the condition and, if possible, a transesophageal echocardiogram should be obtained for confirmation. The clinical presentation of macroscopic fat embolism begins with deteriorated cardiopulmonary function, hypoxemia, hypocapnia, bradycardia, generalized anxiety, and respiratory effort.[12] Taking into account that the clinical picture and the pathophysiology are similar to a pulmonary

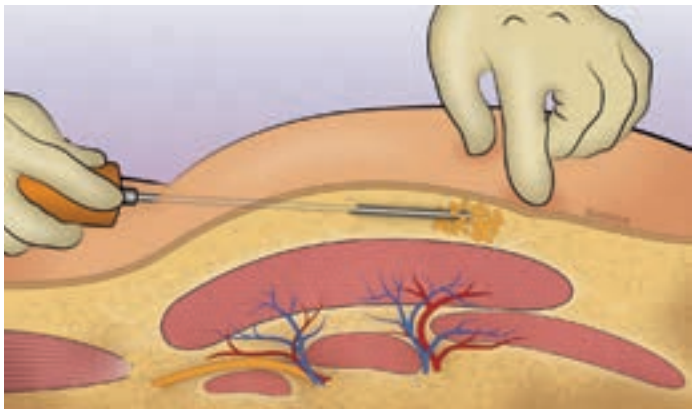

Fig. 4. Place the cannula in a position parallel to the thigh to inject it subcutaneously.

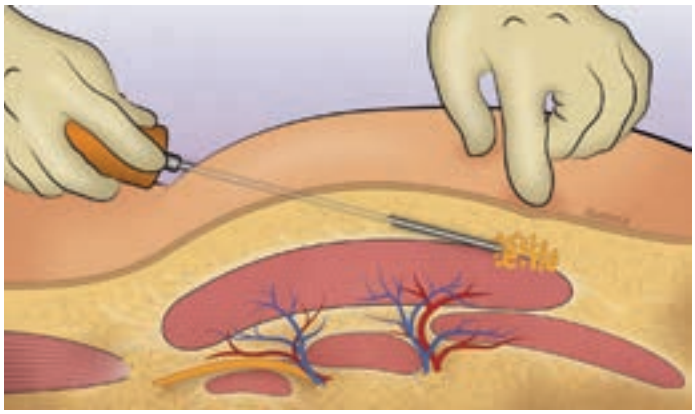

Fig. 5. Avoid injecting under the superficial layers of the muscle.

thromboembolism, treatment must be initiated with ventilatory and cardiologic support, with the objective of acute resuscitation but also support of vascular pressure with amines, primarily dobutamine, because the presence of the embolism increases the pulmonary perfusion pressure, which generates right ventricular stress without an adequate preload.[20] Ventilatory support is also recommended through orotracheal intubation with ventilatory modes that allow spontaneous ventilation and the appropriate use of positive end-expiratory pressure. Alternatives published in clinical cases mention that high doses of rosuvastatin[43] and *N*-acetylcysteine could improve the pulmonary symptoms of fat embolism.[15] However, although statistical analyses are not available at present, the mortality rate associated with macroscopic fat embolism is very high. One detail that must be considered, and which should be the subject of further studies, is the fact that if one supports the theory that the amount of free fatty acids could be one of the factors that triggers microscopic fat embolism, we should consider avoiding the injection of large quantities of fat into highly vascularized areas. In addition, although large-vessel injury can produce a macroscopic fat embolism, multiple lesions of small vessels in highly vascularized areas such as muscles would allow fat absorption in significant amounts, and although they would not produce a macroscopic fat embolism, they could be another predisposing factor leading to microscopic fat embolism (Fig. 8).

Studies using intravascular fat injections in pig models showed that the pattern of cardiac function was "deterioration, improvement, and worsening."[16] This pattern indicates that immediate deterioration follows fat embolism; apparent clinical improvement was observed between 10 and 30 minutes; but at 30 to 60 minutes, the pigs gradually worsened until death. This information is of vital importance because a patient who has an initial deterioration during surgery may appear to have a recovery period. However, the surgery should be terminated quickly, and specialized care should be sought during that 10 to 60 minutes when the patient appears to improve because, otherwise, the risk of intraoperative death is very high.[16]

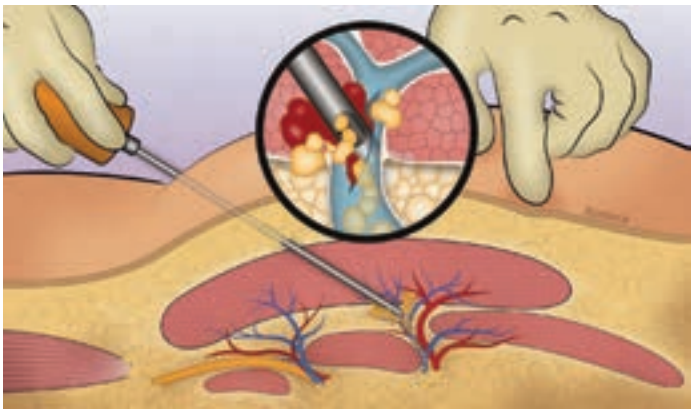

Fig. 6. Introduction of the cannula in an incorrect direction, which causes deep lipoinjection with risk of lesion of upper or lower venous gluteal vessels.

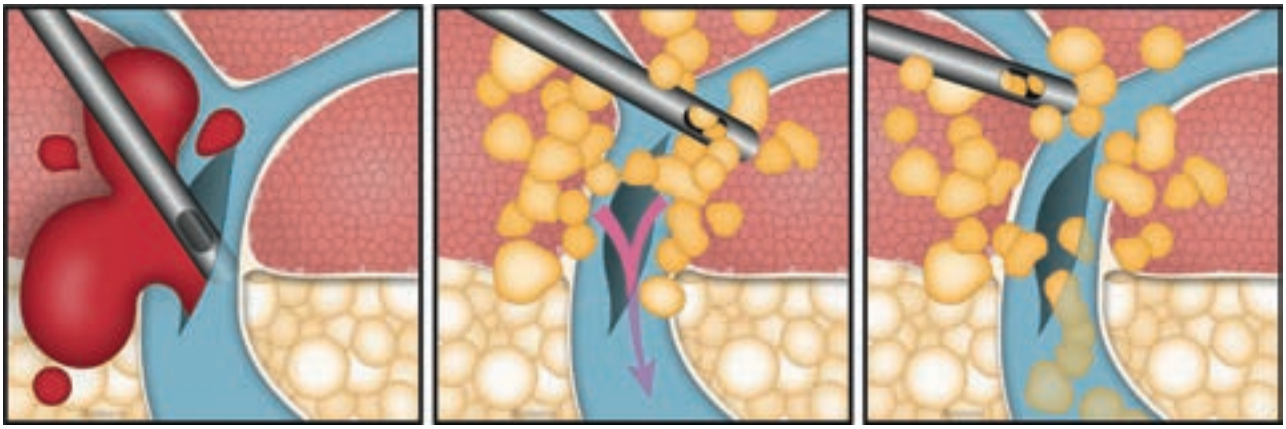

Fig. 7. Introduction of fat into the bloodstream. The vessel does not need to be channeled by the cannula; it is sufficient to lacerate the vein (*left*). Because of the existing negative pressure in the venous system, the vein absorbs fat (*center*). Fat located in the periphery of the injured gluteal vein enters the bloodstream, reaching the vena cava and the heart (*right*).

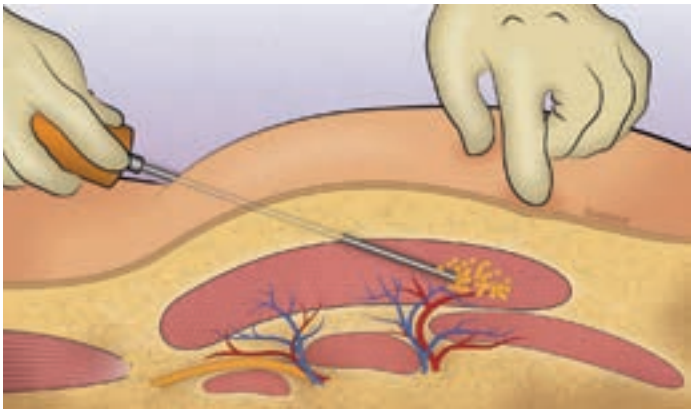

Fig. 8. Although large vessels are not injured, injecting large amounts of fat in areas of high vascularity may be a trigger for microscopic fat embolism. This can produce a very large absorption of microscopic particles of fat into the circulatory torrent. This should be considered for future studies.

Differential Diagnosis of Microscopic and Macroscopic Fat Embolism

The presence of fever and petechiae may confuse the diagnosis and suggest septicemia.[44] The presence of free fat in the blood after liposuction is not always pathognomonic of a fat embolism. Fat has been demonstrated in the urine and sputum of asymptomatic patients who underwent liposuction of more than 900 cc.[35] The presence of fat in the pulmonary capillaries when performing cardiopulmonary resuscitation has also been well documented.[45] These findings are important because 88 percent of the patients who receive cardiopulmonary resuscitation may present a pulmonary embolism that is not secondary to liposuction or lipoinjection.[46,47] In addition, a concordance of the incidence of macroscopic fat embolism is not always found when comparing clinical and postmortem findings because macroscopic fat embolism can be demonstrated in asymptomatic patients in many necropsies.[24] Unfortunately, we do not have any real statistical data on this, and the incidence of macroscopic fat embolism in patients undergoing liposuction or lipoinjection has not been determined.[24]

Recommendations

Because microscopic fat embolism and macroscopic fat embolism are not very common abnormalities reported in plastic surgery, no consensus exists for a specific treatment aside from advanced cardiopulmonary support measures. However, some lines of prevention and treatment based on the experience of fat embolism secondary to bone injuries have proven their usefulness. Interestingly, in a recent article on liposuction trends among plastic surgeons in India, the surgeons who presented the fewest complications were those who operated on more than 70 cases per year. Although an adequate analysis was not performed to evaluate the statistical significance of this assertion, we believe that this finding is an indication that surgeons more accustomed to performing these procedures have better knowledge of the safety limits of the procedure.[48] On the basis of all of the evidence found in this review, we make the following assertions and recommendations (Table 4):

1. We must identify the differences between microscopic fat embolism and macroscopic fat embolism as clinical entities that can be produced by fat manipulation during liposuction and/or lipoinjection.
2. It seems clear that microscopic fat embolism and macroscopic fat embolism are totally different entities that only share a common causal agent, which is the presence of fat in the bloodstream.
3. Because the causal agent of both pathologic conditions is the presence of fat in the blood and because they are otherwise totally different, the terms microscopic fat embolism and macroscopic fat embolism should be

Table 4. General Characteristics of Microscopic Fat Embolism and Macroscopic Fat Embolism

	MIFE	MAFE
Causal agent	Microscopic fat generally in liquid form or micelles that can form microemboli	Macroscopic fat that groups into clots forming macroemboli
Pathophysiology	By effect of lipase, fatty acids are released from microemboli, producing alveolar and capillary irritation with hemodynamic alterations	Fat cells clot immediately obstructing the venous blood vessels and heart by a mechanical effect
Start	24–72 hr postoperatively	Immediate, intraoperative; from the beginning of surgery to 1–2 hr postoperatively
Clinical presentation	Gurd and Wilson criteria for fat embolism; effects on microcirculation; pulmonary, cutaneous, and central nervous system disorders	Similar to pulmonary thromboembolism; mechanical effect on the heart producing sudden cardiac failure
Diagnosis	Clinical; computed tomography (ground-glass opacity and pleural effusion)	Clinical; sudden onset, which begins when the fat is injected; cardiac failure
Prognosis	Mortality of 10–30%, depending on how fast the management starts	Based on published reports almost 99%
Treatment	Respiratory and hemodynamic support measures in the intensive care unit	Currently not described; aggressive cardiovascular support; mainly experimental (ciclesonide, rosuvastatin, percutaneous embolectomy)
Prevention	Avoid injecting liquid fat; adequate hydration; avoid injection in very vascularized areas	The most important factor is to avoid deep intramuscular injection into the medial portion of the gluteus

MIFE, microscopic fat embolism; MAFE, macroscopic fat embolism.

adapted for each abnormality instead of fat embolism syndrome.
4. During lipoinjection, it would be advisable not to inject the upper fraction obtained during liposuction because it contains the greatest amount of free fatty acids, which could be a triggering factor for the appearance of microscopic fat embolism.
5. Adequate hydration of any patient undergoing liposuction should be maintained to facilitate the removal of fatty acids that enter the bloodstream.
6. Lipoinjection of fat into highly vascularized areas, such as muscle, should be avoided to reduce the risk of the introduction of large amounts of fat into the bloodstream.
7. Deep intramuscular injections into the gluteal region should be avoided, especially in the medial portion adjacent to the piriformis muscle, to avoid injuring gluteal vessels.
8. The surgical procedure should be stopped in the case of a sudden deterioration in the general state of the patient, bearing in mind the possibility of having introduced fat into the bloodstream, especially if infiltrating the gluteal muscles.
9. Any signs of respiratory distress, confusion, fever, or petechiae in the first 72 hours postoperatively should be considered to be very important.
10. The use of methylprednisolone or even ciclesonide during the preoperative period should be evaluated as an appropriate preventive measure.

CONCLUSIONS

Microscopic fat embolism and macroscopic fat embolism have appeared as complications associated with aesthetic procedures where fat is manipulated for body contour improvement, such as liposuction and gluteal lipoinjection. In this study, we found that very few scientific medical reports have investigated these two complications, which have the highest morbidity and mortality rates associated with liposuction and gluteal lipoinjection. One cause of this lack of reporting may be failure to identify and make diagnoses of the abnormalities. MIFE and MAFE are entities that must be considered so that we can make appropriate and timely diagnoses to prevent further problems. Both of these complications involve the introduction of fat into the bloodstream; however, their clinical presentation, management, prevention, and prognosis are completely different. Although microscopic fat embolism is presented secondary to biochemical processes because of microcirculatory irritation and has a good prognosis if treated in a timely and appropriate manner, macroscopic fat embolism is secondary to mechanical processes produced by the macroscopic entry of fat into the bloodstream that produces cardiac collapse and is usually fatal. As a basic measure, adequate hydration to prevent MIFE and avoiding deep intramuscular gluteal injections in the case of MAFE are highly recommended.

Lázaro Cárdenas-Camarena, M.D.
Innovare Cirugía Plástica Especializada
Av Verona 7412
Fraccionamiento Viila Verona
Zapopan, Jalisco, México
drlazaro@drlazarocardenas.com

REFERENCES

1. International Society of Aesthetic Plastic Surgery. Available at: https://www.isaps.org/wp-content/uploads/2017/10/GlobalStatistics2016-1.pdf. Accessed April 19, 2017.
2. Cárdenas-Camarena L, Lacouture AM, Tobar-Losada A. Combined gluteoplasty: Liposuction and lipoinjection. *Plast Reconstr Surg.* 1999;104:1524–1531; discussion 1532–1533.
3. Cárdenas-Camarena L. Lipoaspiration and its complications: A safe operation. *Plast Reconstr Surg.* 2003;112:1435–1441; discussion 1442–1443.
4. Cárdenas-Camarena L, Arenas-Quintana R, Robles-Cervantes JA. Buttocks fat grafting: 14 years of evolution and experience. *Plast Reconstr Surg.* 2011;128:545–555.
5. Wang DW, Yin YM, Yao YM. Internal and external carotid artery embolism following facial injection of autologous fat. *Aesthet Surg J.* 2014;34:NP83–NP87.
6. Teimourian B, Rogers WB III. A national survey of complications associated with suction lipectomy: A comparative study. *Plast Reconstr Surg.* 1989;84:628–631.
7. El-Ali KM, Gourlay T. Assessment of the risk of systemic fat mobilization and fat embolism as a consequence of liposuction: Ex vivo study. *Plast Reconstr Surg.* 2006;117:2269–2276.
8. George J, George R, Dixit R, Gupta RC, Gupta N. Fat embolism syndrome. *Lung India* 2013;30:47–53.
9. Illouz YG. Surgical remodeling of the silhouette by aspiration lipolysis or selective lipectomy. *Aesthetic Plast Surg.* 1985;9:7–21.
10. Fournier PF, Otteni FM. Lipodissection in body sculpturing: The dry procedure. *Plast Reconstr Surg.* 1983;72:598–609.
11. Weiler J, Taggart P, Khoobehi K. A case for the safety and efficacy of lipoabdominoplasty: A single surgeon retrospective review of 173 consecutive cases. *Aesthet Surg J.* 2010;30:702–713.
12. Cárdenas-Camarena L, Bayter JE, Aguirre-Serrano H, Cuenca-Pardo J. Deaths caused by gluteal lipoinjection: What are we doing wrong? *Plast Reconstr Surg.* 2015;136:58–66.
13. Mofid MM, Teitelbaum S, Suissa D, et al. Report on mortality from gluteal fat grafting: Recommendations from the ASERF task force. *Aesthet Surg J.* 2017;37:796–806.

14. Costa AN, Mendes DM, Toufen C, et al. Case report. *J Bras Pneumol.* 2007;34:622–625.
15. Liu DD, Kao SJ, Chen HI. N-acetylcysteine attenuates acute lung injury induced by fat embolism. *Crit Care Med.* 2008;36:565–571.
16. Wang AZ, Zhou M, Jiang W, Zhang WX. The differences between venous air embolism and fat embolism in routine intraoperative monitoring methods, transesophageal echocardiography, and fatal volume in pigs. *J Trauma* 2008;65:416–423.
17. Glover P, Worthley LI. Fat embolism. *Crit Care Resusc.* 1999;1:276–284.
18. Filomeno LT, Carelli CR, Silva NC, Filho TE, Amatuzzi MM. Embolia gordurosa: Uma revisao para a practica ortopédica atual. *Acta Ortop Bras.* 2005;13:196–208.
19. Rothmann C, Ruschel N, Streiff R, Pitti R, Bollaert PE. Pulmonary fat embolism after liposuction (in French). *Ann Fr Anesth Reanim.* 2006;25:189–192.
20. Eriksson EA, Pellegrini DC, Vanderkolk WE, Minshall CT, Fakhry SM, Cohle SD. Incidence of pulmonary fat embolism at autopsy: An undiagnosed epidemic. *J Trauma* 2011;71:312–315.
21. Dillerud E. Complications after liposuction. *Plast Reconstr Surg.* 1987;79:844–845.
22. Prologo JD, Dogra V, Farag R. CT diagnosis of fat embolism. *Am J Emerg Med.* 2004;22:605–606.
23. Dillerud E. Suction lipoplasty: A report on complications, undesired results, and patient satisfaction based on 3511 procedures. *Plast Reconstr Surg.* 1991;88:239–246; discussion 247–259.
24. Mellor A, Soni N. Fat embolism. *Anaesthesia* 2001;56:145–154.
25. Franco FF, Tincani AJ, Meirelles LR, Kharmandayan P, Guidi MC. Occurrence of fat embolism after liposuction surgery with or without lipografting: An experimental study. *Ann Plast Surg.* 2011;67:101–105.
26. Mentz HA. Fat emboli syndromes following liposuction. *Aesthetic Plast Surg.* 2008;32:737–738.
27. Habashi NM, Andrews PL, Scalea TM. Therapeutic aspects of fat embolism syndrome. *Injury* 2006:37(Suppl):68–73.
28. Ross RM, Johnson GW. Fat embolism after liposuction. *Chest* 1988;93:1294–1295.
29. Liljedahl SO, Westermark L. Aetiology and treatment of fat embolism: Report of five cases. *Acta Anaesthesiol Scand.* 1967;11:177–194.
30. Akhtar S. Fat embolism. *Anesthesiol Clin.* 2009;27:533–550.
31. Gurd AR, Wilson RI. The fat embolism syndrome. *J Bone Joint Surg Br.* 1974;56:408–416.
32. de Lima e Souza R, Apgaua BT, Milhomens JD, et al. Severe fat embolism in perioperative abdominal liposuction and fat grafting. *Braz J Anesthesiol.* 2016;66:324–328.
33. Cohen L, Engdahl R, Latrenta G. Hypoxia after abdominal and thigh liposuction: Pulmonary embolism or fat embolism? *Eplasty* 2014;14:ic19.
34. Wang HD, Zheng JH, Deng CL, Liu QY, Yang SL. Fat embolism syndromes following liposuction. *Aesthetic Plast Surg.* 2008;32:731–736.
35. Senen D, Atakul D, Erten G, Erdoğan B, Lortlar N. Evaluation of the risk of systemic fat mobilization and fat embolus following liposuction with dry and tumescent technique: An experimental study on rats. *Aesthetic Plast Surg.* 2009;33:730–737.
36. Vedrinne JM, Guillaume C, Gagnieu MC, Gratadour P, Fleuret C, Motin J. Bronchoalveolar lavage in trauma patients for diagnosis of fat embolism syndrome. *Chest* 1992;102:1323–1327.
37. Fulde GW, Harrison P. Fat embolism: A review. *Arch Emerg Med.* 1991;8:233–239.
38. Gallardo X, Castañer E, Mata JM, Rimola J, Branera J. Nodular pattern at lung computed tomography in fat embolism syndrome: A helpful finding. *J Comput Assist Tomogr.* 2006;30:254–257.
39. Nucifora G, Hysko F, Vit A, Vasciaveo A. Pulmonary fat embolism: Common and unusual computed tomography findings. *J Comput Assist Tomogr.* 2007;31:806–807.
40. Sen RK, Prakash S, Tripathy SK, Agarwal A, Sen IM. Inhalational ciclesonide found beneficial in prevention of fat embolism syndrome and improvement of hypoxia in isolated skeletal trauma victims. *Eur J Trauma Emerg Surg.* 2017;43:313–318.
41. Bederman SS, Bhandari M, McKee MD, Schemitsch EH. Do corticosteroids reduce the risk of fat embolism syndrome in patients with long-bone fractures? A meta-analysis. *Can J Surg.* 2009;52:386–393.
42. Levy D. The fat embolism syndrome. *Clin Orthop Relat Res.* 1989;261:271–276.
43. Whalen LD, Khot SP, Standage SW. High-dose rosuvastatin treatment for multifocal stroke in trauma-induced cerebral fat embolism syndrome: A case report. *Pediatr Neurol.* 2014;51:410–413.
44. Christman KD. Death following suction lipectomy and abdominoplasty. *Plast Reconstr Surg.* 1986;78:428.
45. Abbes M, Bourgeon Y. Fat embolism after dermolipectomy and liposuction. *Plast Reconstr Surg.* 1989;84:546–547.
46. Boezaart AP, Clinton CW, Braun S, Oettle C, Lee NP. Fulminant adult respiratory distress syndrome after suction lipectomy: A case report. *S Afr Med J.* 1990;78:693–695.
47. Sevitt S. Significance and classification of fat-embolism. *Lancet* 1960;276:825–828.
48. Laub DR Jr, Laub DR. Fat embolism syndrome after liposuction: A case report and review of the literature. *Ann Plast Surg.* 1990;25:48–52.
49. Eriksson EA, Rickey J, Leon SM, Minshall CT, Fakhry SM, Schandl CA. Fat embolism in pediatric patients: An autopsy evaluation of incidence and etiology. *J Crit Care* 2015;30:221.e1–221.e5.
50. Methil B. Current trends of liposuction in India: Survey and analysis. *Indian J Plast Surg.* 2015;48:249–262.
51. Fourme T, Vieillard-Baron A, Loubières Y, Julié C, Page B, Jardin F. Early fat embolism after liposuction. *Anesthesiology.* 1998;89:782–784.