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Fat embolism following liposuction: A systematic review of reported cases ☆

Pouria Chaghamirzayi[a], Mojtaba Ahmadi Nejad[b], Mohammad Azizmanesh[a], Mohammad Reza Maghsoudi[c], Soroush Nematollahi[d], Javad Karimi Rozveh[a,*]

Introduction

Liposuction or suction-assisted lipectomy is a common cosmetic operation worldwide. Liposuction is a surgical procedure in which subcutaneous fatty tissue is removed using a vacuum. The main application of liposuction is in the area of body contouring and changing the body's shape. Liposuction was introduced in the early 1980s and has made many technological and technical advances over the years.[1,2] Possible complications associated with liposuction include bruising, seroma formation, temporary weight gain, and paraesthesia. Dangerous complications associated with liposuction include fat embolism, deep vein thrombosis, and pulmonary embolism. In these cases, immediate and timely medical intervention is crucial.[3,4] Fat embolism is the presence of fat globules in the circulatory system. Fat embolism syndrome (FES) is the widespread distribution of these emboli that disrupt the capillary bed and microcirculation, subsequently causing a systemic inflammatory syndrome.[5,6] The entry of fat into the bloodstream can occur in two forms, leading to two distinct pathologies: microscopically or macroscopically.[7] More precise terms have been proposed to avoid confusion: MIFE (Microscopic Fat Embolism) and MAFE (Macroscopic Fat Embolism). MIFE occurs when fat enters the bloodstream at a microscopic level, resulting in FES. Conversely, MAFE happens when fat enters macroscopically, causing direct blood vessel occlusion.[7-10] FES is a rare but potentially fatal consequence of end-organ damage.[11,12] Diagnosing and treating fat embolism and FES are challenging for clinicians.[6]

From the [a]Clinical Research Development Unit of Shahid Madani Hospital, Alborz University of Medical Sciences, Karaj, Iran; [b]Department of Surgery, Alborz University of Medical Sciences, Karaj, Iran; [c]Department of Emergency Medicine, Alborz University of Medical Sciences, Karaj, Iran; and [d]Tehran Heart Center, Cardiovascular Diseases Research Institute, Tehran University of Medical Sciences, Tehran, Iran

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* Address reprint requests to Javad Karimi Rozveh, Clinical Research Development Unit of Shahid Madani Hospital, Alborz University of Medical Sciences Building Number 25, west Bahar St, Golshahr St, Karaj, Iran.

E-mail address: Karimirozveh.j@gmail.com (J. Karimi Rozveh).

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Since 1983, several studies have reported fat embolism and FES after liposuction with and without other cosmetic procedures.[13,14] Considering the challenges in diagnosing and treating fat embolism and FES, especially in less recognized conditions such as after liposuction, we systematically reviewed the reported cases of fat embolism or FES after liposuction. This study aimed to comprehensively describe the clinical manifestations, underlying conditions, diagnosis, and management of fat embolism (MAFE/MIFE) following liposuction.

Material and methods

The present study was conducted as a systematic review in accordance with the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses)[15] guideline. This study was previously registered in the Prospective International Register of Systematic Reviews (PROSPERO) under the ID: CRD42023404808.

Eligibility criteria

This study included only case reports/records and case series that met the following criteria:

- Diagnosis of fat embolism or fat embolism syndrome after liposuction without autologous fat injection or injection of soft tissue fillers.
- Patients older than 18 years.

Information sources and search strategy

A comprehensive literature search was conducted in various medical databases, including PubMed, Google Scholar, Cochrane, EMBASE, MEDLINE, and Scopus. The study was conducted without a time limit until December 31, 2023. Studies without English-language abstracts were excluded from the study. The following terms were queried: “Fat Embolisms,” “Fat Embolism,” “Fat Embolism Syndrome,” “Fat emboli,” “fat embolus,” AND “Lipectomies,” “Aspiration Lipectomy,” “Lipolysis,” “Suction,” “Suction Lipolysis,” “Liposuction,” “Liposuctions,” “Lipoplasty,” and “Lipoplasties”. In addition, we thoroughly checked the reference lists of the selected studies and the associated reviews to identify any relevant studies that may have been overlooked in the electronic search. The full text of non-English studies that contained English abstracts were translated using Google Translate, a translation program developed by Google in Mountain View, California, USA.

Selection and data collection process

The search results were extracted and documented using EndNote X20 software. Five authors independently screened the articles to remove duplicates. The lead author reviewed the extracted data. All discrepancies were resolved by consensus discussion in face-to-face meetings. A standardized database for data extraction was created by compiling the following data: Authors, year of publication, country, study design, sample size, gender, age, body mass index, presence of comorbidities, sites of liposuction, concurrent procedures, type of anesthesia, time interval, clinical manifestations, para-clinical and laboratory findings, diagnostic methods, treatments (including mechanical ventilation, ICU admission, and length of hospital stay), and outcomes. Data were classified as “Not mentioned or not available (Missing)” if specific characteristics were missing or unavailable.

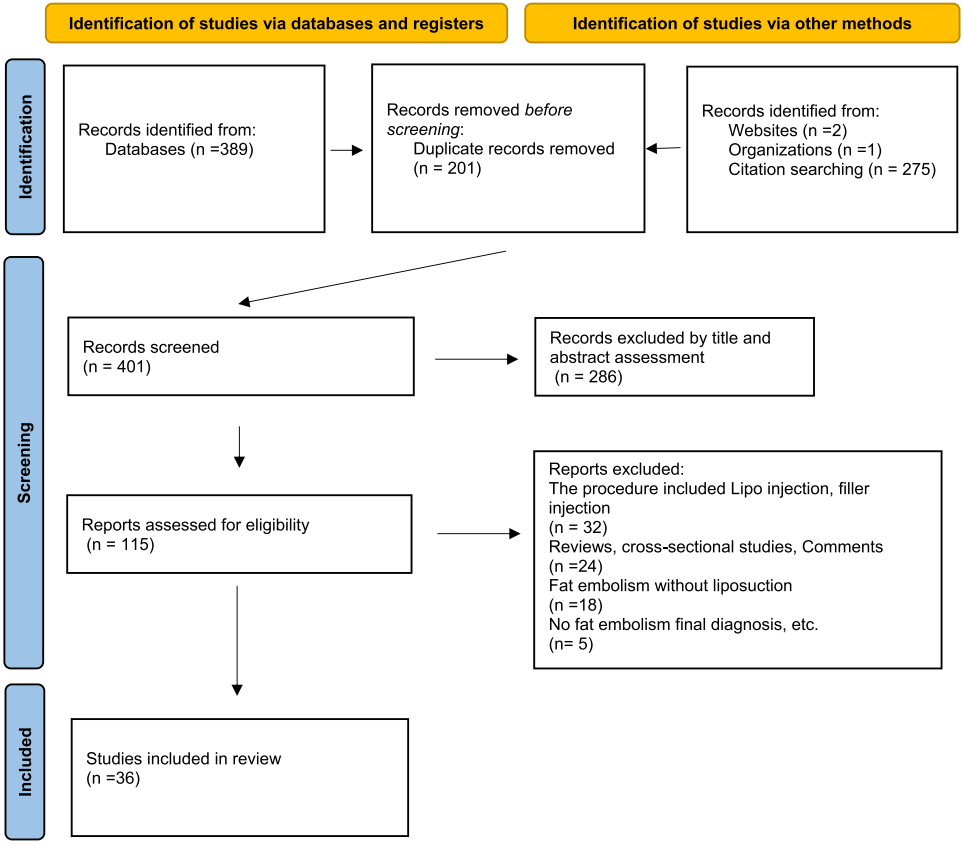

Fig. 1. Flowchart illustrating the study selection process. (Color version of figure is available online.)

Results

Included studies characteristics

A total of 389 studies were identified through a comprehensive database search, and a further 275 studies were obtained through a careful review of the reference lists. A total of 667 studies were identified. After the deduplication process, a total of 401 studies were selected. After completing the title, abstract, full-text screening, and eligibility assessment, 36 studies were deemed suitable for inclusion in this review[13,14,16-49] (see Fig. 1). Of the total 36 studies examined, six documented three cases on two separate occasions, while two studies reported two cases. Thirty-five patients were included in this research. The research included 14 different nations, with the majority of studies originating from the United States. The first study was published in 1983 as a medical report on one patient by Hunter et al.[14] With the exception of one case series, all of the studies conducted were case reports. The characteristics of the individual studies are listed in Table 1.

Patient demographics and medical history

Regarding the gender of the patients, 6/35 (17.1%) were male and 29/35 (82.9%) were female. The ages of the patients ranged from 21 to 82 years. Ten patients had a body mass index (BMI)

Table 1
Summary of included studies characteristics.

Cases*	Author	Year	Country	Study type	Count
1	Ansari et al.[1]	2023	USA	Case report	1
2,3	Qi et al.[2]	2023	China	Case series	2
4	Ding et al.[3]	2022	China	Case report	1
5	Kaiser et al.[4]	2022	Brazil	Case report	1
6	Pham et al.[5]	2022	Vietnam	Case report	1
7	Foula et al.[6], Foula et al.[7]	2022, 2019	Egypt	Case report	1
8	Scarlat et al.[8]	2021	Romania	Case report	1
9	Kadar et al.[9]	2021	USA	Case report	1
10	Saon et al.[10]	2019	USA	Case report	1
11	Thamwiwat et al.[11], Grome et al.[12]	2019, 2018	USA	Case report	1
12	Antara et al.[13]	2019	India	Case report	1
13	Zhibin et al.[14]	2018	China	Case report	1
14	Cantu et al.[15]	2017	USA	Case report	1
15	Ali et al.[16]	2017	UK	Case report	1
16	Sasaki et al.[17]	2017	Japan	Case report	1
17	Doumit et al.[18], Zeidman et al.[19]	2016, 2013	USA	Case report	1
18	Vidua et al.[20]	2015	India	Case report	1
19	Byeon et al.[21]	2015	Korea	Case report	1
20	Hostiuc et al.[22]	2014	Romania	Case report	1
21	Erba et al.[23]	2011	Switzerland	Case report	1
22	Shaikh et al.[24]	2008	Qatar	Case report	1
23	Wessman et al.[25]	2007	USA	Case report	1
24	Rothmann et al.[26]	2006	France	Case report	1
25,26	Platt et al.[27]	2002	USA	Case report	2
27	Folador et al.[28].	1999	Brazil	Case report	1
28	Scroggins et al.[29]	1999	USA	Case report	1
29	Fourme et al.[30]	1998	France	Case report	1
30	Laub and Laub[31]	1990	USA	Case report	1
31	Boezaart et al.[32]	1990	South Africa	Case report	1
32	Abbes et al.[33]	1989	France	Case report	1
33	Ross et al.[34]	1988	USA	Case report	1
34	Christman and Christman.[35]	1986	USA	Case report	1
35	Hunter et al.[36]	1983	USA	Case report	1

USA: United States of America, UK: United Kingdom.
* The number of each case in the tables is the same.

between 21.6 and 65 kg/m^2. Smoking habits were reported in 4/8 (50%). Regarding comorbidity, 12/21 (57.2%) patients were found to have no known underlying diseases. Table 2 shows the demographic characteristics and medical history of each case.

Procedures characteristics and types of anesthesia

In 9/27 (33.4%) patients, only liposuction of the abdomen/flank was performed. In 20/27 (74.1%), liposuction was performed on the abdomen/flank with or without other regions. Liposuction of the upper extremities was performed on 4/27 (14.8%). Liposuction of the lower extremities was performed on 9/27 (33.4%). Liposuction of the back was performed on 6/27 (22.3%). Liposuction of the breast/axilla/chest was performed on 3/27 (11.5%). Liposuction of the pelvis/buttocks was performed on 3/27 (11.2%). Liposuction of the face was performed in 1/27 (3.7%). The fat volume removed during liposuction was reported in 10 studies and ranged from 0.3 to 13.5 liters. 23/35 (65.8%) patients underwent liposuction only, and 12/35 (34.2%) underwent simultaneous procedures, with 7/12 (58.3%) patients undergoing abdominoplasty. A total of 11/16 (68.7%) patients received general anesthesia, while 5/16 (31.3%) received local anesthesia. The procedures, characteristics, and types of anesthesia for each patient are shown in Table 3.

Table 2
Summary of patients' demographics and medical history.

Cases	Age (years)	Sex	BMI (kg/m^2)	Smoking	Comorbidity
1	54	Female	NM	Yes	Endometriosis, anxiety, depression
2	39	Female	NM	NM	NM
3	35	Male	NM	NM	NM
4	29	Female	28.5	No	No
5	37	Female	NM	NM	NM
6	37	Female	21.6	NM	No
7	29	Female	38.5	NM	No
8	30	Female	NM	NM	No
9	26	Female	27.8	No	Anemia, Anxiety, insomnia
10	52	Female	NM	Yes	No
11	38	Female	30	NM	No
12	34	Male	32.2	NM	Hypothyroidism
13	40	Female	NM	NM	NM
14	60	Female	NM	NM	NM
15	45	Female	65	NM	Morbid obesity, legs lipoedema, and depression
16	29	Female	NA	NA	NA
17	24	Female	NM	NM	Klippel-Trenaunay syndrome
18	39	Female	NM	Yes	NM
19	21	Male	32.5	NM	No
20	56	Female	NM	NM	NM
21	46	Female	NM	NM	Bronchial asthma
22	46	Female	NM	NM	Diabetes mellitus and hypertension
23	31	Male	NM	No	Sickle cell trait
24	24	Female	NM	NM	No
25	82	Female	NM	NM	NM
26	50	Male	NM	NM	NM
27	40	Female	NM	No	Endometriosis
28	54	Female	NA	NA	NA
29	29	Female	NM	NM	No
30	51	Female	NM	NM	NM
31	39	Female	NM	NM	No
32	55	Female	NM	NM	NM
33	44	Female	28.6	Yes	No
34	56	Male	27.2	No	No
35	37	Female	NM	NM	NM

BMI: Body mass index, NM: Not mentioned, NA: Not available.

Timing and clinical features of patients

In 4/34 (11.8%) patients, the first signs/symptoms occurred during the procedure. In 5/30 (16.7%), the first signs/symptoms occurred 2 hours or less after the procedure. In 33/34 (97.1%) patients, the first signs/symptoms appeared 72 hours or less after or during the procedure. Only 1/34 patients experienced their first signs/symptoms more than 72 hours after the procedure (13 days). Various primary clinical features were reported in patients, including respiratory, cardiac, and neurological manifestations. Cardiac arrest occurred in 2/4 (50%) of patients in whom signs/symptoms developed during the procedure. Loss of consciousness outside the medical center was reported as the primary sign/symptom in 3/34 (8.9%) patients less than 48 hours after the procedure. The details of the primary clinical features and timing for each patient are shown in Table 4.

Regarding clinical manifestations, dyspnea was reported in 19/20 (95%), tachypnea in 15/20 (75%), tachycardia in 15/20 (75%), hypotension in 10/17 (58.9%), fever in 13/21 (61.9%), altered mental status in 15/18 (83.3%), and cardiac arrest in 8/32 (25%) of patients. Cough was reported in 4/6 (66.7%), hemoptysis in 2/5 (40%), cyanosis in 5/10 (50%), bradycardia in 1/21 (4.7%), chest pain in 7/10 (70%), petechial rash in 8/16 (50%), and retinal changes in 3/8 (37.5%). No patient

Table 3
Summary of procedures and types of anesthesia.

Cases	Liposuction sites	Volume (L)	Other procedures*	Anesthesia
1	Abdomen	NM	No	NM
2	Abdomen and lumbar region	NM	No	NM
3	Abdomen and lumbar region	1.8	No	General
4	Abdomen and Arm	NM	No	NM
5	Abdomen	NM	No	NM
6	Abdomen	NM	Yes: BA and ABP	NM
7	Abdomen, back, thighs, and upper arms	6.5	No	General
8	Abdomen	1.5	No	Local
9	NM	NM	Yes: ABP	General
10	Axilla, pectorals, and the back	NM	BA	NM
11	Abdomen, flanks, and back	NM	No	Local
12	Abdomen, back, and face	4.5	No	General
13	A large area of the abdomen and arm	NM	No	NM
14	NM	NM	No	NM
15	Bilateral lower leg and knee	10-13.5	No	General
16	Abdomen	NA	No	NA
17	Right thigh liposuction	3.0	No	NM
18	Breasts, abdomen, thighs, and arms	NM	No	NM
19	NM	NM	No	General
20	Bilateral thigh	NM	No	Local
21	Abdomen and both thighs	4.5	Yes: BA and BSSV	General
22	NM	NM	ABD	NM
23	Abdomen and flanks	NM	No	General
24	Buttocks	NM	No	Local
25	Abdomen	NM	YES: ABD	NM
26	NM	Nm	No	NM
27	NM	NM	YES: H and O	NM
28	NA	NA	No	NA
29	Abdomen, hip, and trochanteric area	0.6	No	General
30	Abdomen, mid-thigh, knee, and trochanteric area	0.4	Yes: MP, ABP and ADRr	Local
31	Upper thighs and knee	1.3	No	General
32	Waist and xiphoid liposuction	NM	Yes: CFR	NM
33	NM	NM	Yes: ABP and ADRr	NM
34	Flanks	0.5	Yes: ABP	General
35	Abdomen	NM	Yes: ADRr	NM

NM: Not mentioned, NA: Not available, Volume: volume of aspirated fat based on Liter.

* BA, breast augmentation (implant); ABP, abdominoplasty; H and O, hysterectomy and oophorectomy; BSSV, bilateral stripping of the long saphenous veins; MP, mastopexy (implant gel); ADRr, abdominal rectus diastasis repair; CFR, cutaneous fat resection.

with jaundice was reported. Other clinical manifestations included decreased urine output, fatigue, nausea, and vomiting.

Laboratory findings

Anemia (hemoglobin $<$ 13 g/dL) was found in 16/19 (84.2%) patients, although only 2/19 (10.5%) patients had a drop in hemoglobin of more than 20%. Leukocytosis (WBC $> 10 \times 10^9$/L) was observed in 10/15 (66.7%) and leukopenia in 1/15 (6.7%) patients. Thrombocytopenia (platelet count $< 150 \times 10^3$/MCL) was reported in 4/11 (36.3%), with a decrease of more than 50% seen in only 1/11 (9.1%) patients. A PaO2/FiO2$\leq$ 200 was reported in 15/20 (75%) of patients. Elevated levels of D-dimer, troponin (I, T), NT-ProBNP, C-reactive protein, and estimated erythrocyte sedimentation rate (ESR) were reported in several studies. The laboratory findings of the individual patients are listed in Table 5.

Table 4
Summary of primary clinical manifestations and timing.

Cases	Timing*	Primary clinical features
1	Less than 12 h after procedure	Dyspnea, cough, fever
2	Less than 12 h after procedure	Dyspnea, drowsiness, tachycardia
3	Less than 12 h after procedure	Sudden onset dyspnea, cyanosis, altered mental status
4	During procedure	Sudden onset dyspnea, chest pain, dizziness, violent emesis
5	NM	Sudden onset dyspnea, chest pain
6	Less than 12 h after procedure	Dyspnea, fatigue, chest discomfort
7	During procedure	Sudden cardiac arrest
8	During procedure	Abdominal pain, Cardiac arrest
9	Less than 72 h after procedure	Respiratory failure, altered mental status
10	Less than 12 h after procedure	Dyspnea
11	Two hours after the procedure	Chest pain, tachycardia
12	End of the procedure	Altered mental status, sudden cardiac arrest
13	Less than 12 h after procedure	Altered mental status
14	72 h after procedure	Dyspnea and lethargy
15	36-39 h after procedure	Tachycardia, respiratory acidosis
16	13 d after procedure	was suspected of having a pulmonary embolism
17	18 h after procedure	Right thigh pain, fever
18	Less than 24 h after procedure	Was found unresponsive
19	Less than 6 h after procedure	Dyspnea, fever, hemoptysis, impaired mental status
20	Less than 48 h after procedure	Cyanosis, Skin, and mucosa petechial rashes
21	Less than 72 h after procedure	Respiratory distress, fever, dizziness
22	Less than 72 h after procedure	Lethargy, dyspnea, tachycardia, fever
23	End of the procedure	Dyspnea
24	During procedure	Altered mental status, dyspnea
25	Less than 48 h after procedure	Was found unresponsive
26	Less than 6 h after procedure	Was found unresponsive
27	72 h after procedure	Sudden onset dyspnea, fever
28	Less than 48 h after procedure	Dyspnea, tachypnea
29	One h after procedure	Sudden anxiety, dyspnea
30	44-60 h after procedure	Chest pain, dyspnea, cyanosis
31	End of the procedure	Fever, tachycardia, confusion, tachypnea
32	Less than 72 h after procedure	Isolated diplopia, left homonymous, lateral hemianopia
33	Less than 72 h after procedure	Tachypnea, dyspnea, cyanosis, fever
34	Less than 24 h after procedure	Tachycardia, tachypnea
35	Less than 24 h after procedure	Anxious, cyanosis, tachycardia, tachypnea

* Timing: Interval time between the end of the procedure and the presentation of first signs or symptoms.
NM, not mentioned.

Imaging and other paraclinical findings

A chest X-ray (CXR) was performed in 16 patients. In 2/16 patients (12.5%), the CXR showed normal results. In the remaining patients (14/16, 87.5%), bilateral diffuse infiltrations with or without consolidation were detected in several cases, primarily consistent with acute respiratory distress syndrome (ARDS). Computed tomography (CT) scans of the chest were performed on 17 patients, four of whom underwent computed tomography pulmonary angiography (CTPA). CTs of the chest without contrast enhancement were performed in 5 patients. Bilateral ground-glass opacities (GGOs) were found in 10/17 (58.9%) of the patients who underwent chest CT scans. Bilateral consolidation was seen in 7/17 (41.2%) of patients who underwent chest CT scans. No signs of pulmonary embolism or filling defects were detected in 9/12 (75%) patients who underwent contrast-enhanced chest CT scans. In comparison, pulmonary arterial filling defects in the form of fat emboli were reported in 1/12 (8.4%) of patients, and signs of pulmonary embolism were reported in 1/12 (8.4%). Other imaging studies of the lungs, including pulmonary angiography (PA), pulmonary arteriogram (Pa), perfusion study (PS), and lung scan, were also performed and showed a high probability of pulmonary embolism in 3/4 (75%) of patients. A CT scan of the brain was performed in 2 patients, and magnetic resonance imaging (MRI) of the brain was

Table 5
Summary of patients' laboratory findings.

Cases	Anemia	Leukocytosis	Thrombocytopenia	PaO2/FiO2≤200	Others*
1	Y	Y	N	Y	Elevated CRP levels
2	Y	NM	N	N	-
3	N	NM	N	Y	-
4	Y*	N	N	Y	Elevated D-dimer, NT-pro-BNP, Troponin I, and CK levels
5	NM	NM	NM	NM	-
6	NM	NM	NM	N	Elevated D-dimer, NT-ProBNP, and Troponin T levels
7	Y	Y	Y	Y	Elevated D-dimer level
8	NM	NM	NM	NM	-
9	Y	Y	N	Y	Elevated D-dimer, NT-pro-BNP, Troponin T, CRP, and ESR levels
10	Y	Y	NM	NM	-
11	Y†	NM	NM	Y	Elevated Troponin, CKMB, and CK levels
12	NM	NM	NM	NM	-
13	NM	NM	NM	N	-
14	NM	NM	NM	NM	-
15	Y	Y	N	Y	Elevated CRP and Troponin T levels
16	Y	Y	NM	NM	Elevated CRP levels
17	Y†	N	Y‡	N	Elevated Total bilirubin level
18	NM	NM	NM	NM	-
19	N	N	N	Y	Negative CRP and elevated D-dimer level
20	NM	NM	NM	NM	Hypoglycemia
21	NM	NM	NM	NM	-
22	NM	NM	NM	Y	-
23	Y	Y	N	Y	-
24	N	Y	NM	N	Elevated CRP and Troponin I levels
25	NM	NM	NM	NM	-
26	NM	NM	NM	NM	-
27	Y	N	Y	N	Elevated ESR level
28	NA	NA	NA	NA	-
29	Y	NM	N	Y	Elevated CRP level
30	NM	NM	NM	Y	-
31	Y	N	Y^	Y	Leukopenia
32	Y	N	N	NM	-
33	Y	Y	N	Y	-
34	NM	NM	NM	NM	-
35	NM	NM	NM	Y	-

Anemia: Hemoglobin<13 g/dL, Leukocytosis: White Blood Cell>10×10^9/L, Thrombocytopenia: Platelet count<150×10^3/MCL.
Y, yes; N, no, NM, not mentioned; NA, not available; NT-ProBNP, N-terminal pro–B-type natriuretic peptide; CK, creatine kinase; ESR, erythrocyte sedimentation rate; CRP, C-reactive protein.
* D-dimer>0.50 mg/L.
† Drop more than 20%,
‡ Drop more than 50%.

performed in 3 patients. The imaging examination methods and findings for each patient are listed in Table 6.

Further paraclinical findings in each patient are listed in Table 7. An electrocardiogram (ECG) was performed in 6 patients, and sinus tachycardia was detected in 4/6 (66.6%). ST-elevation myocardial infarction was detected in 1/6 (16.7%) of patients, while 1/6 (16.7%) of patients had a normal ECG. Transthoracic echocardiography (TTE) was performed in 9 patients, which was normal in 1/9 (11.2%) patients, while the other patients (8/9, 88.8%) had different findings such as pulmonary hypertension, hyperkinesia, and enlargement of the right ventricle. Bronchoalveolar lavage (BAL) was performed in 4 patients whose cytologic examination revealed lipid-laden macrophages. Macroscopic and microscopic autopsy examinations were performed on eight patients that showed fat embolism.

Table 6
Summary of patients' imaging study's findings.

C*	Imaging studies	Findings
1	Chest CTs/ CXR	Bilateral GGOs, septal thickening (crazy-paving pattern), pneumothorax/ Bilateral diffuse patchy airspace disease (14)*, pneumothorax
2	Chest CCTs (CTPA)	Diffused nodular opacities, septal thickening, GGOs (5)*, no filling defects
3	Chest CCTs (CTPA)	Diffused nodular opacities, bilateral GGOs, consolidation, septal thickening (6)*, no filling defects
4	Chest CCTs (CTPA)	Extensive GCOs, consolidation (10)*/ No filling defects
5	Chest CCTs (CTPA)	Multiple pulmonary arterial filling defects (with attenuation similar to subcutaneous fat), infarction
6	Chest CCTs	Multiple pulmonary arterial filling defects (lipid droplets at segmental arteries),
7	CXR	Bilateral diffused pulmonary opacities
8	No	-
9	Chest CCTs/CXR/Brain CTs/MRI	Diffused mixed GCOs and consolidation, no filling defects/ Bilateral confluent opacities/ Mild diffuse cerebral edema/ Infarct within globi pallidi and cerebral white matter
10	Chest CCTs/ CXR	Bilateral GCOs and central consolidation, no filling defects/ Bilateral airspace opacities (4) †
11	CXR/ APCTs	Normal/ No retroperitoneal bleeding
12	No	-
13	Brain CTs/MRI/Chest CTs	Mild low-intensity signal in the left hemisphere, fat droplets/ Large area of hyperintense foci on T2W/ Normal
14	No	-
15	CXR	Bilateral generalized infiltration
16	Chest CCTs	Pulmonary artery dilatation without an overt thrombus
17	Chest CTs/CXR	GGOs and bilateral plural effusion
18	No	-
19	Chest CCTs/CXR	Bilateral diffuse airspace opacities (10)* / Bilateral diffuse haziness
20	No	-
21	Chest CTs	Bilateral generalized GGOs and plural effusion, peripheral subpleural triangular opacities
22	Chest CCTs/Brain MRI	Bilateral Consolidation, No PE / Nonconfluent hyperintense signals in basal and optic thalamus.
23	Chest CCTs/CXR	Bilateral GGOs, No PE/ Bilateral multifocal airspace opacities (2)*
24	Chest CCTs/CXR/Brain MRI	Bilateral consolidation, PE (7)*/ Bilateral Snowstorm aspect (2)*/ Normal
25	No	-
26	No	-
27	CXR/ Pulmonary PS	Normal/ High probability of PTE
28	NA	NA
29	Chest CTs/CXR/PA	Bilateral GGOs, consolidation (10)*/ Diffuse bilateral infiltrations (2)*/ No PE
30	CXR/ Pa	Bilateral Consolidation/ Lower lobes atelectasis, peripheral pruning
31	CXR	Bilateral infiltrations
32	No	-
33	CXR	Bilateral patchy infiltrations
34	Lung scan/ Pa	Suggestive of pulmonary emboli/Bilateral peripheral pulmonary emboli
35	CXR	Diffuse infiltrations

* Cases, CCTs: Contrast-enhanced computed tomography scan, CTPA: Computed tomography pulmonary angiography, CTs: Computed tomography scan, CXR: Chest x-ray, MRI: Magnetic resonance imaging, PS: Perfusion study, PA: Pulmonary angiography, Pa: Pulmonary arteriogram, GGOs: Ground glass opacities, NA: Not available. APCTs: Abdominopelvic computed tomography scan, PE: Pulmonary embolism.

† Days to partial/complete resolution.

Table 7
Summary of patients' other paraclinical findings.

Cases	Other para clinical findings
1	No
2	No
3	No
4	No
5	NM
6	No
7	Lower limbs CDI: No DVT / TTE: Global hyperkinesia (EF: 38%)
8	Histopathological findings: Fat pulmonary embolism
9	BAL cytology: Lipid-laden macrophage.
10	TTE: mild TR, EF: 65%
11	EKG: STEMI/ Coronary angiogram: Diffuse blockage coronary arteries/ TTE: hypokinesia, EF: 29%, Macroscopic coronary thrombus assessment: fat embolism
12	Histopathological findings: pulmonary and cerebral fat embolism
13	NM
14	Histopathological findings: pulmonary and cerebral fat embolism
15	ECG: Sinus tachycardia/ TTE: Hyperdynamic systolic function in both ventricles
16	TTE: Dilated pulmonary artery
17	Right lower extremity MRI: Mild edema
18	Histopathological findings: Systematic fat embolism
19	ECG: Normal/ TTE: RV enlargement (Sign of PH), EF: 47%, LV dilation.
20	Histopathological findings: Pulmonary and brain thrombus and fat droplet emboli
21	No
22	TTE: Right Heart enlargement, PH, Normal EF/ PAC: PH
23	ECG: Sinus tachycardia
24	ECG: Sinus tachycardia/ TTE: Septal hyperkinesia/ BAL cytology: Lipid-laden macrophage
25	Histopathological findings: Pulmonary fat emboli
26	Histopathological findings: Pulmonary fat emboli
27	Lower limbs CDI: No DVT
28	BAL cytology: Lipid-laden macrophage
29	BAL cytology: Lipid-laden macrophage/ ECG: Sinus tachycardia/ TTE: Normal
30	NM
31	PAC: Normal
32	No
33	PAC: PH
34	Histopathological findings: Cardiac, pulmonary, and Brain fat embolism
35	NM

CDI, color doppler imaging; DVT, deep vein thrombosis; TTE, transthoracic echocardiogram; EF, ejection fraction; BAL, broncho alveolar lavage; TR, tricuspid regurgitation; ECG, electrocardiogram; STEMI, ST elevation myocardial infarction; PH, pulmonary hypertension; RV, right ventricle; LV, left ventricle; PAC, pulmonary artery catheterization; NM, not mentioned.

Final diagnosis and diagnostic methods

Fat embolism syndrome (FES) was reported as the final diagnosis in 19/35 (54.3%) patients and fat embolism was declared as the final diagnosis in the remaining patients (16/35, 45.7%). The final diagnosis was determined based on clinical presentation and imaging studies in many studies. 1/35 (2.9%) patients were simultaneously diagnosed with FES and pulmonary thromboembolism (PTE), and 1/35 (2.9%) had a coronary fat embolism. Based on clinical evolution reported in each study we determined the final diagnosis as macroscopic and microscopic fat embolism (MAFE, MIFE). MAFE is identified through imaging studies, such as CT or MRI scans, which reveal the presence of fat droplets within the vasculature, or through direct macroscopic assessment of tissue samples obtained via biopsy or autopsy. This diagnosis is confirmed when large, visible fat globules are found within the pulmonary, cerebral, or systemic circulation. MIFE is equivalent to fat embolism syndrome (FES). The diagnosis is based on clinical findings, such as respiratory distress, neurological symptoms, and petechial rash, along with supportive imaging studies like chest X-rays, chest CTs or brain MRI showing characteristic findings, and laboratory

Table 8
Summary of final diagnosis and diagnostic methods.

Cases	Authors' final diagnosis	MIFE	MAFE	Diagnostic methods
1	FES	Yes	No	Clinical manifestation, imaging, exclude other causes
2	FES	Yes	No	Clinical manifestation, imaging
3	FES	Yes	No	Clinical manifestation, imaging
4	FES	Yes	No	Excluding other possible causes
5	Pulmonary FE	No	Yes	Imaging
6	Pulmonary FE	No	Yes	Imaging
7	FES	Yes	No	Excluding other possible causes, Gurd and Wilson's criteria
8	Pulmonary FE	No	Yes	Macroscopic and microscopic autopsy assessment
9	FES	Yes	No	Excluding other possible causes, BAL cytology
10	FES	Yes	No	Clinical manifestation, imaging
11	Coronary FE	No	Yes	Macroscopic coronary thrombus assessment (PCI)
12	Pulmonary and cerebral FE	Yes	Yes	Histopathologic autopsy assessment
13	FES	Yes	Yes	Clinical manifestation, imaging
14	FES	Yes	No	Macroscopic and microscopic autopsy assessment
15	FES	Yes	No	Clinical manifestation, Gurd and Wilson's criteria
16	FES	Yes	No	Clinical manifestation, imaging
17	FES	Yes	No	Clinical manifestation, Gurd and Wilson's criteria
18	Systematic FE	Yes	Yes	Macroscopic and microscopic autopsy assessment
19	FES	Yes	No	Clinical manifestation, imaging
20	FES, PTE	Yes	No	Clinical manifestation, microscopic autopsy assessment
21	FES	Yes	No	Clinical manifestation, imaging
22	FES	Yes	No	Clinical manifestation, imaging
23	Pulmonary FE	Yes	No	Clinical manifestation, imaging
24	Pulmonary FE	Yes	Yes	Clinical manifestation, imaging
25	Pulmonary FE	Yes	No	Macroscopic and microscopic autopsy assessment
26	Pulmonary FE	Yes	No	Macroscopic and microscopic autopsy assessment
27	FES	Yes	No	Clinical manifestation, imaging
28	FES	Yes	No	Clinical manifestation, BAL cytology
29	FES	Yes	No	Clinical manifestation, BAL cytology
30	FES	Yes	No	Clinical manifestation, imaging
31	FES	Yes	No	Clinical manifestation, imaging
32	FE	Yes	No	Clinical manifestation, fundus examination
33	Pulmonary FE	Yes	No	Clinical manifestation, imaging
34	Systematic FE	Yes	Yes	Macroscopic and microscopic autopsy assessment
35	FE	Yes	No	Clinical manifestation, imaging, fundus examination

FES, fat embolism syndrome; FE, fat embolism; BAL, bronchoalveolar lavage; PCI, percutaneous coronary intervention; MAFE, macroscopic fat embolism; MIFE, microscopic fat embolism.

results. This condition is characterized by the presence of microscopic fat globules within the vasculature, which can lead to systemic inflammatory responses and multiorgan dysfunction. MAFE was detected in 9/35 (25.7%) of patients. MIFE was detected in 31/35 (88.6%) of patients. Additionally, 4 patients (11.4%) exhibited clinical, imaging, or histopathological findings that led to a simultaneous diagnosis of both MAFE and MIFE (Fig. 2). The final diagnosis and diagnostic methods for each patient are shown in Table 8.

Management and patients' outcomes

The primary treatment method was indicated as supportive treatment in several studies. Admission to the intensive care unit was reported in 14/15 (93.4%) patients. Mechanical ventilation was performed in 16/21 (76.2%) patients. Corticosteroids were administered in 6/19 (31.6%) patients, and anticoagulants were administered in 6/18 (33.3%). Hospitalization ranged from 1 to 100 days. 9/34 (26.5%) patients died, and 7/8 (87.5%) died 72 hours or less after the procedure. Permanent disability or organ failure was reported in 2/22 (9.1%) of patients. Of the nine patients who died, only liposuction was performed in 7/9 (77.8%), and abdominoplasty was performed in 2/9 (22.3%) patients at the same time. In 4/9 (44.5%) patients, the first signs/symptoms occurred

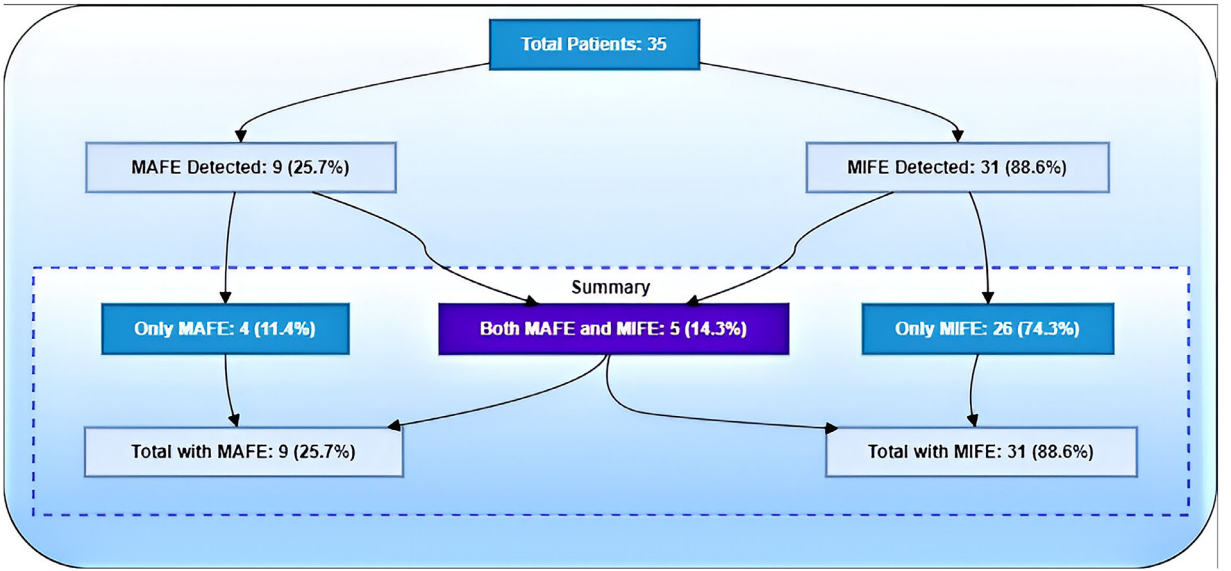

Fig. 2. Macroscopic (MAFE) and microscopic fat embolism (MIFE) as a final diagnosis in patients. (Color version of figure is available online.)

Table 9
Summary of management and patient outcomes.

Cases	ICU*	MV*	Corticosteroids	Anticoagulants	Hospital stays (days)	Outcome/Timing*/POD*
1	NM	N	N	Y†	8	Alive/-/N
2	NM	NM	NM	NM	NM	Alive /-/N
3	Y	Y	NM	NM	NM	Alive/-/N
4	NM	N	Y	Y†	11	Alive/-/N
5	NM	NM	NM	NM	NM	NM/NM/NM
6	Y	NM	NM	NM	7	Alive/-/N
7	Y	Y	Y	N	9	Alive/-/N
8	-	-	-	-	-	Death/0/-
9	Y	Y	Y	N	15	Alive/-/N
10	N	N	Y	N	NM	Alive/-/N
11	Y	Y	Y	Y	9	Alive/-/Y
12	-	-	-	-	-	Death/0/-
13	NM	NM	NM	NM	13	Death/13/-
14	NM	Y	N	Y	NM	Death/NM/-
15	Y	Y	N	Y†	14	Alive/-/N
16	NA	NA	NA	NA	NA	Alive/-/NA
17	Y	Y	N	N	4	Alive/-/N
18	-	-	-	-	-	Darth/1/-
19	NM	Y	Y†	NM	14	Alive/-/N
20	-	-	-	-	-	Death/1/-
21	NM	Y	NM	NM	100	Alive/-/N
22	NM	Y	NM	NM	NM	Alive/-/N
23	Y	N	Y†	Y	NM	Alive/-/N
24	Y	N	N	Y	14	Alive/-/N
25	NM	Y	NM	NM	1	Death/3/-
26	NM	Y	NM	NM	1	Death/1/-
27	NM	NM	Y	Y	NM	Alive/-/N
28	NA	Y	NA	NA	NA	Alive/-/NA
29	Y	N	N	N	3	Alive/-/N
30	Y	N	N	N	6	Alive/-/N
31	Y	Y	N	N	NM	Alive/-/N
32	NM	-	N	Y	NM	Alive/-/Yes
33	Y	Y	Y	N	12	Alive/-/No
34	Y	NM	N	N	2	Death/2/-
35	NM	Y	NM	NM	NM	Alive/-/No

* ICU, intensive care unit admission; MV, mechanical ventilation; Timing, The interval time between procedure and occurrence of death (days); POD, Permanent organ failure/ disability.

† Anticoagulants, prophylactic dose; Corticosteroid, not therapeutic doses. Y, yes; N, No; NM, not mentioned; NA, not available.

less than 12 hours after (3/9, 33.4%) or during the procedure (1/9, 11.1%). The treatment and outcomes of individual patients are shown in Table 9.

Macroscopic and microscopic fat embolism

MAFE was diagnosed in 9 patients, and only MAFE was diagnosed in 4 patients. First, we describe the 4 patients with only MAFE as the final diagnosis' clinical features and outcomes. Patients' ages ranged from 30 to 38 years and all were women with no known comorbidity. In all patients, the liposuction sites included the abdomen (abdomen only in three, and in one abdomen, flanks, and back). One patient (1/4, 25.0%) underwent concomitant procedures with liposuction including breast augmentation and abdominoplasty. Timing of symptoms onset reported in three patients including during the procedure (n = 1), 2 hours after the procedure (n = 1), and less than 12 hours after the procedure (n = 1). Primary clinical features included respiratory symptoms (n = 2), chest pain (n = 2), and cardiac arrest (n = 1). In 2 patients contrast contrast-enhanced chest CTs confirmed macroscopic pulmonary fat embolism. Biopsy and

autopsy assessments revealed macroscopic fat embolism in the other 2 patients, respectively. Outcomes were reported in 3 cases with one (1/3, 33.3%) death.

In 5 patients simultaneous MAFE and MIFE were diagnosed. Patients' ages ranged from 24 to 56 years with no known comorbidity (hypothyroidism in 1). Two were men and 3 were women. Liposuction sites included the abdomen with other sites (n = 3), only flanks (n = 1), and only buttocks (n = 1). A total of 1/5 (20.0%) patient underwent concomitant procedure with liposuction (abdominoplasty). Timing of symptoms onset included during the procedure (n = 1), immediately after (n = 1), less than 12 hours (n = 1), and less than 24 hours (n = 2) after the procedure. Primary clinical features included neurologic symptoms (n = 4), cardiac arrest (n = 1), and cardiopulmonary symptoms (n = 1). MAFE was diagnosed based on imaging studies (n = 3), and autopsy findings (n = 2). The mortality rate was high (4/5, 80.0%), Fig. 3.

Totally in 9 patients, MAFE was diagnosed with or without concomitant MIFE. Patients' ages ranged from 24 to 56 years with no known comorbidity (hypothyroidism in 1). Two were men (2/9, 22.2%) and 7 were women (7/9, 77.8%). Liposuction sites included the abdomen with (n = 4) or without (n = 3) other sites, only flanks (n = 1), and only buttocks (n = 1). Two patients (2/9, 22.2%) underwent concomitant procedures with liposuction. Timing of symptoms onset reported in 8 patients included during the procedure, up to 2 hours after, less than 12 hours after, and less than 24 hours after the procedure each in 2/8 (25.0%) patients. Primary clinical features included respiratory, neurologic symptoms, and cardiac arrest. The mortality rate was 62.5% (5/8).

MIFE without simultaneous MAFE was diagnosed in 26 patients. Patients' ages range from 21 to 82 years. Comorbidity was reported in eight patients (8/15, 53.3%). 22/26 (84.6%) patients were woman and 4/26 (15.4%) were men. Liposuction sites included the abdomen with or without other sites in 12/18 (66.7%) patients. 9/26 (34.6%) patients underwent concomitant procedures with liposuction. Timing of symptoms onset included during the procedure (2/26, 7.7%), immediately up to 2 hours after (3/26, 11.5%), less than 12 hours after (6/26, 23.1%), 12 to 72 hours after (14/26, 53.8%), and more than 72 hours after (1/26, 3.8%) the procedure. Primary clinical features included respiratory and neurologic symptoms with or without fever and skin petechia in several cases. The mortality rate was 15.4% (4/26), (Fig. 4, Table 10).

Discussion

This systematic review investigated the clinical, laboratory, and therapeutic characteristics of patients with fat embolism after liposuction. Due to the possibility of fat embolism after fat injection, it is not possible to differentiate the cause of fat embolism in fat injection combined with liposuction. Therefore, patients with fat injections were not included in the study. Thus, this study investigated the occurrence of fat embolism including MAFE and MIFE following liposuction alone and with other procedures without fat injection. Fat embolism and FES after liposuction were reported in different countries, mainly in young people.

Fat embolism postliposuction

Our results show clinical presentations in patients with various conditions, including dyspnea, neurologic abnormalities, and petechiae. The classic triad of FES consists of hypoxemia (respiratory insufficiency), neurologic abnormalities, and petechiae, which are the major criteria of Gurd and Wilson for the diagnosis of FES.[50-53] Pulmonary manifestations have been described as one of the most common early symptoms of FES, including dyspnea, tachypnea, hypoxemia, and respiratory insufficiency.[54,55] In addition, the minor criteria of Gurd and Wilson, such as fever, tachycardia, and renal signs, have been reported in several cases without jaundice being detected. Schoenfeld's quantitative criteria for the diagnosis of FES also consider factors such as petechial rash, hypoxemia, fever, tachycardia, and confusion.[56] Symptoms may vary depending on the organs affected,[53] so different signs and symptoms may occur.

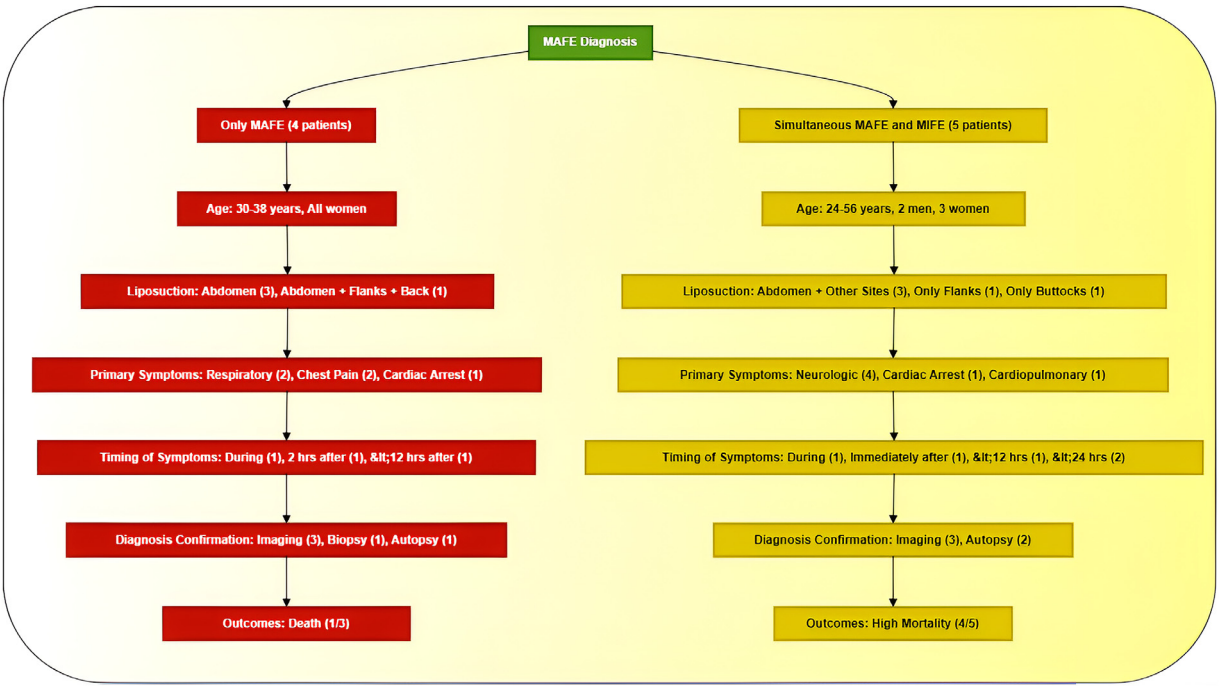

Fig. 3. Summary of key findings in patients with MAFE with and without MIFE. (Color version of figure is available online.)

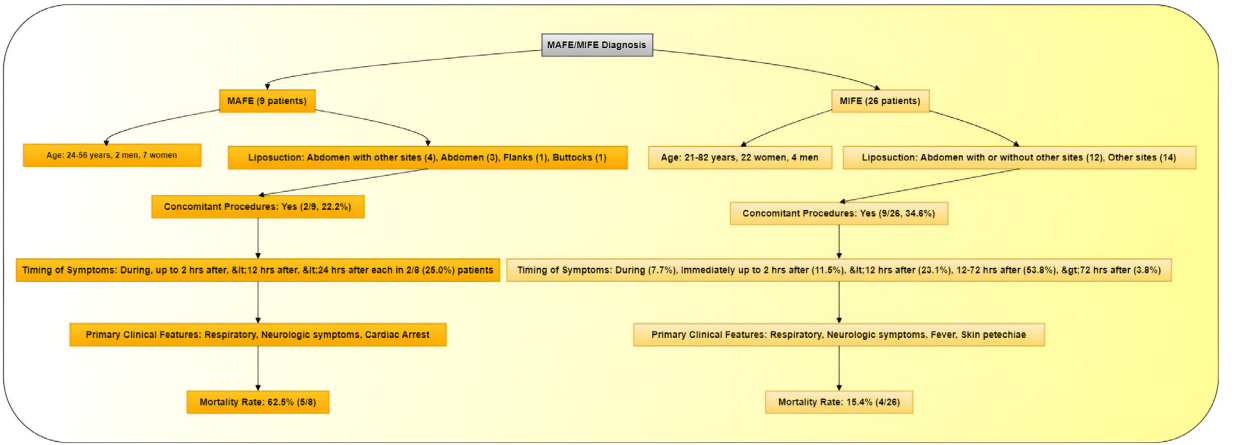

Fig. 4. Summary of key findings in patients with MAFE versus MIFE. (Color version of figure is available online.)

Table 10
Diagnosis of MAFE and MIFE postliposuction.

Diagnosis	n	Age	Gender	Comorbidities	Liposuction sites	Concomitant procedures	Timing of symptoms onset	Primary clinical features	Mortality rate
Only MAFE	4	30-38 y	All women	None	Abdomen only (3), Abdomen + Flanks + Back (1)	(1/4, 25.0%)	During (1), 2 h after (1), <12 h after (1)	Respiratory symptoms, chest pain, cardiac arrest	33.3% (1/3)
MAFE and MIFE	5	24-56 y	2 men, 3 women	(1/5, 20.0%)	Abdomen + Other Sites (3), Only Flanks (1), Only Buttocks (1)	(1/5, 20.0%)	During (1), Immediately after (1), <12 h after (1), <24 h after (2)	Neurologic symptoms, cardiac arrest, cardiopulmonary symptoms	80.0% (4/5)
MAFE (Total)	9	24-56 y	2 men, 7 women	(1/9, 11.1%)	Abdomen with (n = 4) or without (n = 3) other sites, Only Flanks (n = 1), Only Buttocks (n = 1)	(2/9, 22.2%)	During, up to 2 h after, <12 h after, <24 h after each in 2/8 (25.0%) patients	Respiratory, neurologic symptoms, cardiac arrest	62.5% (5/8)
Only MIFE	26	21-82 y	22 women, 4 men	8/26 (30.8%)	Abdomen with or without Other Sites (12), Other Sites (14)	(9/26, 34.6%)	During (2/26, 7.7%), Immediately up to 2 h after (3/26, 11.5%), <12 h after (6/26, 23.1%), 12-72 h after (14/26, 53.8%), >72 h after (1/26, 3.8%)	Respiratory, neurologic symptoms with or without fever and skin petechiae	15.4% (4/26)

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

In traumatic patients, fat embolism syndrome typically begins between 24 and 72 hours after the initial injury. However, there are rare cases in which it occurs within 12 hours or up to 14 days later.[52,57] In contrast, in 16 of 34 (47.1%) patients who experienced fat embolism/FES after liposuction, the first signs and symptoms occurred less than 2 hours after or during the procedure. This indicates a faster onset of symptoms after liposuction compared to traumatic cases.

Anemia, PaO2/FiO2≤200, leukocytosis, thrombocytopenia, elevated D-dimers, troponin, NT-ProBNP, C-reactive protein, and erythrocyte sedimentation rate (ESR) have been reported in several cases of fat embolism/FES after liposuction. Anemia, thrombocytopenia, and an elevated ESR are among Gurd and Wilson's minor criteria for the diagnosis of FES[50,51]. A PaO2/FiO2 ratio of ≤200 indicates moderate to severe acute respiratory distress syndrome (ARDS), reflecting respiratory insufficiency[58], which is one of Gurd and Wilson's major criteria for the diagnosis of FES.[50,51]

CTs of the chest of several patients showed bilateral diffuse infiltration, ground glass opacities, and consolidation without evidence of pulmonary embolism or filling defects. These findings are consistent with previous studies that have reported similar chest imaging patterns in patients with fat embolism/FES.[13,59,60] In particular, the absence of an arterial filling defect on chest imaging does not rule out the possibility of fat embolism. Bronchoalveolar lavage (BAL) is another tool for the diagnosis of fat embolism in which Leiden macrophages have been detected. However, these findings in BAL are not specific to the diagnosis of fat embolism and may also occur in other clinical conditions.[61]

There is no specific treatment for fat embolism or fat embolism syndrome. However, various treatments have been introduced, but their efficacy is controversial.[62] Treatment of FES includes maintaining good arterial oxygenation and intravascular volume and using albumin for volume resuscitation. Mechanical ventilation and positive end-expiratory pressure (PEEP) may be necessary to maintain oxygenation. Ineffective medications include steroids, heparin, alcohol, and dextran.[63-66] Due to the lack of specific treatment, the relatively high mortality rate, timely diagnosis, and initiation of supportive treatment in these patients is therefore crucial. Delay in the diagnosis and treatment of fat embolism has been shown to be associated with increased mortality and morbidity.[67,68]

The overall mortality rate was 26.5%. In traumatic FES patients, the mortality rate was 7 to 10%[6,69,70]. Compared to liposuction-related fat embolism, facial fat grafting-related arterial embolism exhibits a lower mortality rate of 9.8%. The procedural differences highlight specific nuances, with liposuction involving varied body regions and higher fat volumes, while facial fat grafting targets distinct facial areas with a mean volume of 21.5 mL. Complications from liposuction span respiratory, cardiac, and neurological issues, whereas arterial embolism in facial fat grafting predominantly results in visual and neurological symptoms, including blindness. The findings emphasize the need for tailored precautions and procedural guidelines in distinct aesthetic interventions[71].

Macroscopic and microscopic fat embolism postliposuction

This study examines the clinical features, diagnostic methods, and outcomes of patients with macroscopic fat embolism (MAFE) and macroscopic intravascular fat embolism (MIFE) following liposuction procedures. MIFE occurs when fat enters the bloodstream at a microscopic level, resulting in Fat Embolism Syndrome (FES). Conversely, MAFE happens when fat enters macroscopically, causing direct blood vessel occlusion.[7-10] Among patients diagnosed with only MAFE, symptoms such as respiratory issues, chest pain, and cardiac arrest emerged from during to within 12 hours post-procedure, with a 33.3% mortality rate. In patients with simultaneous MAFE and MIFE, symptoms included neurologic issues, cardiac arrest, and cardiopulmonary problems, with a high mortality rate of 80%. The total MAFE group showed a 62.5% mortality rate. The clinical features and outcomes of patients with macroscopic fat embolism (MAFE) following liposuction procedures highlight significant mortality. Consistent with recent findings in

the medical literature, our study observed that MAFE often presents with acute cardiorespiratory failure due to the mechanical obstruction of large blood vessels by fat emboli.[7,72] The immediate onset of symptoms such as respiratory distress, chest pain, and cardiac arrest within 12 hours postprocedure underscores the rapid and severe nature of this condition. The high mortality rate supports the notion that the prognosis is dire. This aligns with previous studies suggesting that the complications associated with MAFE are predominantly mechanical and often fatal if not promptly managed.[7,72] Therefore, early recognition and aggressive supportive care, including ventilatory and cardiological support, are critical in improving patient outcomes.[9]

In patients with only MIFE, symptoms ranged from respiratory and neurologic issues to fever and skin petechia, occurring from during to more than 72 hours postprocedure, with a 15.4% mortality rate. Our study's observed symptomatology of post-liposuction MIFE presentations corresponds with previous reports of FES that describe a wide array of symptoms, including respiratory distress, neurologic disturbances, fever, and petechiae.[11,73] We found approximately half of the patients with post-liposuction only MIFE presented with signs/symptoms onset less than 12 hours after or during the procedure indicating faster onset compared to traumatic FES.[52,57] Despite fat entering the bloodstream in many patients, the variability in clinical manifestation of MIFE suggests that factors such as dehydration and elevated free fatty acid levels in the immediate postoperative period exacerbate the condition. This supports our findings including different timing and clinical features, reinforcing the role of individual patient factors and procedural circumstances in the development of MIFE.[62,74] The persistent mortality rate of 10-30% for MIFE, underscores the severity of this condition and the need for continued research and prevention efforts[7].

Strength, limitations, and future research

The main strength of this study is the comprehensive systematic review that provides a thorough understanding of fat embolism including MAFE and MIFE after liposuction. It is the first comprehensive study on this topic and provides evidence-based insights into clinical manifestations, diagnostic approaches, and treatment strategies. This systematic review acknowledges limitations in the evidence, including data derived from case reports, differences in reporting and diagnostic criteria, retrospective nature, language limitations, and a lack of comprehensive data. It also points to potential publication bias, as studies with poorer results or unusual presentations may be published more frequently. The lack of complete data in the literature limited our analysis of crucial variables, including surgical and anesthesia times, liposuction techniques, and the extent of liposuction.

The findings of this study have several implications for clinical practice, policy development, and future research. Clinically, it highlights the importance of early detection of fat embolism or fat embolism syndrome in patients who have undergone liposuction, especially given some cases' rapid onset of symptoms. The lack of universally accepted diagnostic criteria emphasizes the need for high suspicion and careful patient monitoring after liposuction. Furthermore, the high mortality rate in the first three days after liposuction emphasizes the critical role of timely intervention and supportive care. These findings underscore the importance of standardized reporting and expansion of diagnostic criteria for fat embolism and fat embolism syndrome. Establishing clear guidelines for diagnosing and managing these conditions is essential to improve patient outcomes and safety. In this context, there is a need for extensive and prospective studies that can provide strong evidence on the incidence, risk factors, and optimal management of fat embolism after liposuction. In addition, research on preventive measures and strategies to minimize the occurrence of fat embolism in cosmetic surgery procedures would be valuable.

Declaration of competing interest

None.

CRediT authorship contribution statement

Pouria Chaghamirzayi: Conceptualization, Methodology, Software, Writing – original draft, Writing – review & editing. **Mojtaba Ahmadi Nejad:** Visualization, Data curation, Supervision. **Mohammad Azizmanesh:** Conceptualization, Data curation, Writing – original draft. **Mohammad Reza Maghsoudi:** Data curation, Writing – original draft. **Soroush Nematollahi:** Writing – original draft, Writing – review & editing, Software, Methodology. **Javad Karimi Rozveh:** Data curation, Writing – original draft, Validation.

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