European Journal of Paediatric Neurology 48 (2024) 91–100

Contents lists available at ScienceDirect

European Journal of Paediatric Neurology

journal homepage: www.journals.elsevier.com/european-journal-of-paediatric-neurology

Original article

Fat embolism syndrome in Duchenne muscular dystrophy: Report on a novel case and systematic literature review

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ARTICLE INFO

Keywords:
Duchenne muscular dystrophy
Cerebral fat embolism
Bone fractures

ABSTRACT

We report a non-ambulatory 13-year-old boy with Duchenne muscular dystrophy who experienced severe acute respiratory distress syndrome and cerebral fat embolism following elective soft tissue surgery. Post-surgery radiological examination revealed bilateral femoral fractures and marked osteopenia that were believed to have caused disseminated pulmonary and cerebral fat embolism. The patient had never been on glucocorticoid treatment. Five months post-surgery, he remained in a state of minimal consciousness.

A literature review was performed and eleven publications included, providing case reports of a total number of 23 patients with Duchenne muscular dystrophy with fat embolism syndrome. The most common causes were falls from the wheelchair that predominantly resulted in femoral fractures. Median age at the event was around 14 years. Seven patients succumbed to complications of fat embolism. No event was described in the context of surgery. We want to raise awareness that spontaneous unnoticed fractures may occur especially in adolescents with DMD from traumatic injury of large bones and also during elective surgery with a high risk of causing fat embolism with severe sequelae.

1. Introduction

Fat embolism (FE) occurs relatively frequently after trauma and during orthopaedic procedures involving manipulation of intramedullary contents. Fat embolism syndrome (FES) is a rare complication described as the triad of pulmonary distress, neurologic symptoms, and petechial rash [1].

FE may occur unnoticed in many patients; however, FES is reported to occur in up to 11 % of patients with femoral fractures [2,3], particularly after prolonged immobilisation.

The main causative factor of FE in the context of femoral fractures is believed to entail a sudden increase of intramedullary pressure peaking up to 1400 mmHg (normal values 30–50 mmHg). As a consequence, bone marrow is released into the circulation by venous drainage in the distal metaphysis of the femur. Both, mechanical factors and a systemic inflammation have been discussed as underlying mechanisms [4]. Small deformable fat globules (7–10 μm) are thought to pass the pulmonary capillary system [5,6], causing endothelial damage of different tissues. Symptoms typically develop 24–72 h after the initial injury often with respiratory distress. Cerebral fat embolism syndrome (CFE) is observed in approximately 80–85 % of FES and may range from mild and transient confusion to severe encephalopathy and coma [4,6]. In most instances, neurological symptoms are transient [7].

Duchenne muscular dystrophy (DMD) is a severe and progressive muscle disease in children caused by mutations in the *DMD* gene [8]. While current care recommendations have helped to improve care and survival, most affected boys still die at a young age, from cardiac and respiratory failure [9]. Single, also fatal cases of FES have been described from traumatic bone fractures [10,11]. Patients with DMD are also at risk for rhabdomyolysis from different causes like trauma and surgery [12]. We here report a first case of FES in a boy with DMD in the context of elective surgery. We systematically analyse all previously reported cases of FES in DMD to provide data on risk factors, imaging and outcome.

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https://doi.org/10.1016/j.ejpn.2023.11.012
Received 4 September 2023; Received in revised form 28 November 2023; Accepted 30 November 2023
Available online 6 December 2023

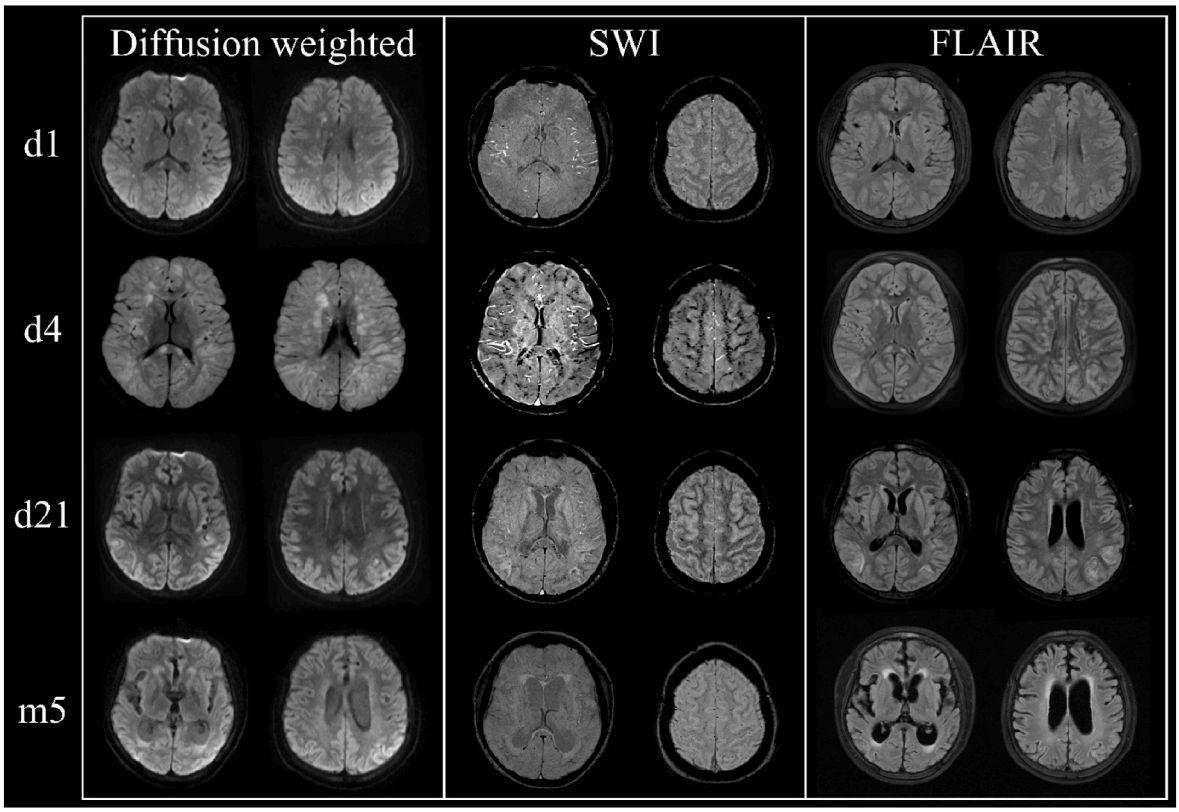

Fig. 1. Cranial MRI one day post-surgery reveals multiple, dot-shaped diffusion restrictions and on susceptibility weighted imaging (SWI) signal extinctions in the inner border zone and basal ganglia (d1). Follow-up MRIs on day 4 and 21 (d4 and d21) are indicative of cytotoxic cerebral oedema with focal diffusion-restricted lesions as well as microbleedings with typical "walnut kernel" sign (SWI, maximum on d4). MRI on day 21 and at 5 months (m5) show progressive global atrophy and periventricular gliosis (FLAIR). SWI susceptibility weighted imaging, FLAIR Fluid-attenuated inversion recovery.

2. Methods

2.1. Part I: case report

We reviewed the medical history, clinical findings, and imaging data of a patient with FES following orthopaedic surgery. Follow-up cerebral magnetic resonance imaging (cMRI) and clinical follow-up were analysed in a time frame of five months following FE. The patient and his parents gave their informed consent to the inclusion in this report.

2.2. Part II: systematic literature review

This systematic review was carried out in accordance with the updated Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines [13].

2.2.1. Search strategy

The bibliographic databases PubMed, Lilacs, Web of Science and ScienceDirect were searched for literature on the incidence of FES in DMD using the following search terms: "Fat embolism AND Duchenne dystrophy", "Fat embolism AND muscular dystrophy". Furthermore, reference lists of each study and previous systematic reviews were manually reviewed for additional reports. No filters regarding the year of publication were applied. The search was completed on 01.07.2023.

2.2.2. Study selection

Search results were extracted and documented using EndNote by Clarivate. Duplicates were removed and records were screened by title and/or abstract. Those reports included after screening were then obtained and read in their entirety for the formal inclusion in our analysis.

2.2.3. Inclusion/exclusion criteria

Original studies and case reports describing paediatric and adult patients with confirmed diagnosis of DMD who had suffered FES were included in the review. In addition, we only included studies which reported the events that had led to FES and described the clinical course of the patients. Narrative or systematic reviews, conference abstracts and animal experiments were excluded. No limitations regarding the language of publication were applied.

2.2.4. Synthesis methods

Data from included studies were collected and analysed using a Microsoft Excel 2016 for Windows spreadsheet (Microsoft Corporation). Graphical displays were performed using Microsoft PowerPoint 2016 for Windows (Microsoft Corporation).

3. Results

3.1. Case report

A 13-year-old obese boy of Kurdish ancestry with DMD had been admitted for elective soft tissue surgery due to increasing joint pain and contractures (bilateral fixed club feet at 50 % extension, knee flexion at 30 % and hip flexion at 20 %) with the aim of enabling passive verticalization.

He had been diagnosed with DMD at the age of 6 years, genetic testing revealed a deletion of exon 46–48 in the *DMD* gene. The boy had never received corticosteroid therapy. He had lost ambulation at the age of 9 years and hence required a wheelchair and support for transfers.

Multi-level soft-tissue surgery was performed in general intravenous anaesthesia and avoidance of muscle relaxants in the knowledge of high risk of malignant hyperthermia. Anaesthesia and operation time could

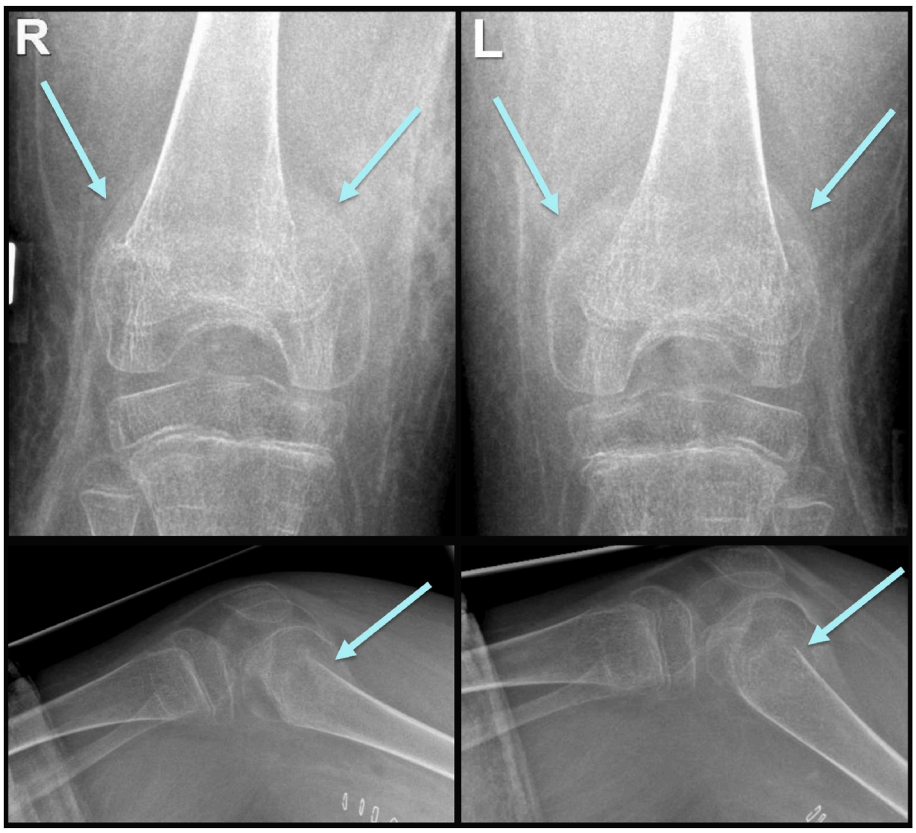

Fig. 2. Post-operative X-ray imaging of lower extremities of right and left distal femur – knee – tibia, demonstrating pronounced osteopenia and recent severe compression fractures of both distal femora (arrows). Upper images: anterior-posterior, lower images: lateral; R right, L left.

be reduced to overall 154 min by performing the operation by two surgeons simultaneously. Intra-operatively, full passive extension of hips and knee joints as well as ankle joint dorsiflexion was demonstrated. Following surgery, the boy was initially responsive, but became increasingly soporous, requiring respiratory support and ventilation after 24 h post-surgery. An X-ray of the lungs was compatible with severe ARDS. Ventilation could be slowly weaned until he was extubated at day 9 post surgery. Electrocardiogram (ECG) and echocardiography were normal and ruled out a patent foramen ovale. High fever persisted from day 2 for 5 days. An inflammatory response was noticed; however, microbial testing was negative. Tonic seizures with apnoea, tachycardia and gaze deviation occurred on day 3 post-surgery but could be controlled by anticonvulsive medication. Tachycardia, mydriasis and flush-like erythema were thought to result from sympathetic overstimulation. Temporary oliguria was treated with furosemide.

Cranial MRI showed early diffusion-restricted areas and increasing cytotoxic oedema with microbleedings indicative of diffuse white matter injury. The MRI pattern led to the diagnosis of disseminated fat embolism (Fig. 1). In view of the unidentified causal event leading to fat embolism, X-rays of the lower extremities were carried out that revealed pronounced osteopenia and recent severe compression fractures of both distal femora (Fig. 2).

When re-examined 3- and 5-months post-surgery, the patient remained in a state of minimal consciousness: He showed unintended occasional eye contact and fixation of objects but was unable to intentional verbal or non-verbal communication. He could grasp a ball with both hands and showed reaction to pain, auditory and tactile stimuli.

3.2. Pooled analysis of novel and published cases of FES in individuals with DMD

The literature search yielded a total of 45 records, of which 17 duplicates were removed before screening. Following the initial screening by title and/or abstract, 16 records were excluded and 12 eligible reports were further assessed by full text reading. Of these, 11 studies met inclusion criteria and were included in the analysis (Fig. 3).

In total, our search revealed 23 cases of FES in DMD that had been published between 1992 and 2020. In the following, our case is added as number 24.

Median age at FES was 14.5 years, ranging between 10 and 23 years (Fig. 4).

FES in all published cases occurred after traumatic injury of large bones. All but two boys were non-ambulant at the time of injury. Cause of trauma were minor falls in 21 out of 24 (in the following x/y) (88 %) cases, all occurring out of the wheelchair or scooter or whilst being transferred. Including our case, femoral traumatic fractures were present in 16/24 (67 %) cases. Amongst those were 14/16 (88 %) isolated femoral fractures and 3/24 (13 %) isolated fractures of tibiae or fibulae. In 11/24 (46 %) cases, combined fractures were reported, predominantly consisting of bilateral femoral fractures (7/11, 63 %). In 5/24 (21 %) patients, no fractures were either detected or reported (Fig. 5). Five patients 5/24 (21 %) were described with a history of fractures.

In 17/22 (77 %) children, treatment with steroids was reported, two of whom were still ambulant at the time of FES. Osteopenia or osteoporosis were described in 14/24 (58 %) patients, three of whom had never received steroid treatment (3/14, 21 %).

In two patients (2/24, 8 %), a patent foramen ovale was described.

3.2.1. Symptoms at the onset and course of FES

21/24 (88 %) patients presented with tachypnoea or hypoxia and 19/24 (79 %) with tachycardia (Fig. 6). Over time, all but four patients (20/24, 83 %) required respiratory support, either non-invasive or invasive ventilation during the acute phase. Two patients (2/24, 8 %) required non-invasive ventilation after discharge, one of whom had been

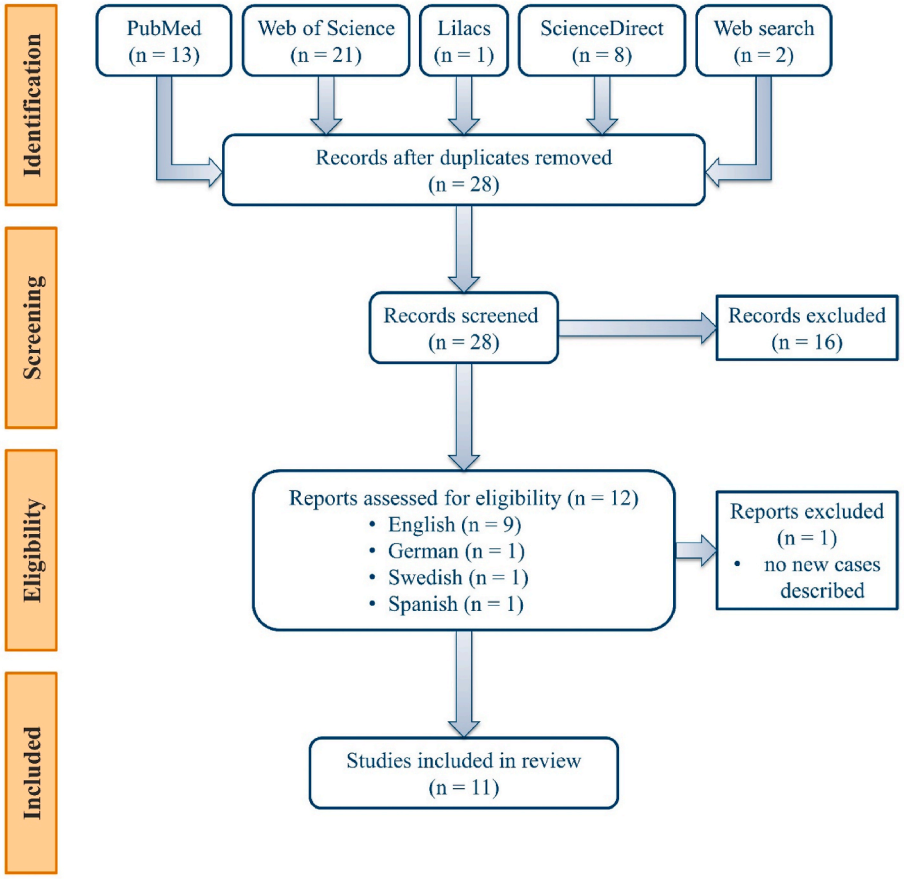

Fig. 3. Literature flowchart depicting the literature search and study selection.

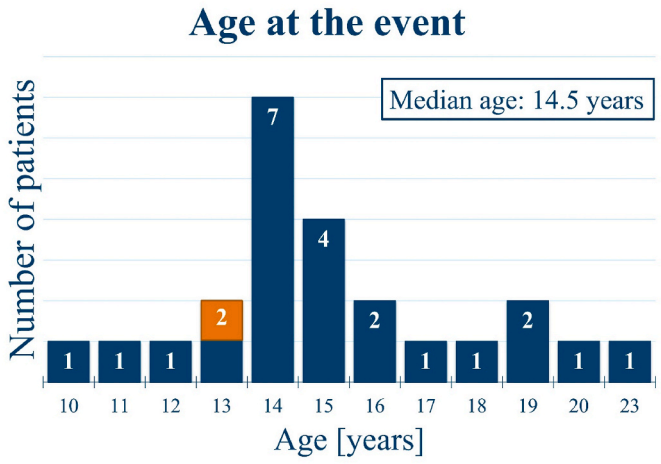

Fig. 4. Age distribution of affected boys with DMD at occurrence of fat embolism syndrome, median age: 14.5 years; blue: cases of the literature review, orange: our case. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

started on non-invasive ventilation (NIV) prior to FE.

In 20/24 (83 %) patients, neurological symptoms were the initial symptom, varying between confusion, agitation, lethargy, seizure, obtundation or unresponsiveness. Neurological symptoms deteriorated in these boys over the course of days, in a few resulting in a state of unresponsiveness and coma.

Seizures were observed in 6/24 (25 %) patients. Bilateral or unilateral slowing of electroencephalogram (EEG) was mentioned in two patients (2/24, 8 %) without epileptic activity. A blurred vision was described in 5/24 (21 %) patients, in 2/24 (8 %) from the outset of symptoms. In 1/24 (4 %) patient, severe headache was one of the initial symptoms.

4/24 (17 %) patients were described with fever as first symptom, however, over the subsequent days, a total of 11/24 (46 %) patients developed high temperatures. Petechiae were described in 6/24 (25 %) patients but only in one patient (1/24, 4 %) as presenting symptom. In 5/24 (21 %) patients a retinopathy ("Purtscher-like") was reported.

3.2.2. *Outcome*

7/24 (29 %) patients died from FES, whereas 13/24 (54 %) showed full recovery. Two patients (2/24, 8 %) stayed in a persistent state of minimal consciousness. One patient (1/24, 4 %) initially presented with neurological impairment that improved over time (Fig. 7).

3.2.3. *Imaging*

A cMRI was carried out in 11/24 (46 %) cases, describing either diffuse punctate emboli or multifocal cortical and subcortical lesions, including the brainstem in one case. In one case, normal brain imaging was reported. Initial computed tomography imaging was performed in 8/24 (33 %) patients; in no case did it reveal abnormalities. In 5/8 (63 %) cases a subsequent cMRI was performed, revealing pathological patterns consistent with FES. No data on long term MRI follow-up was available apart from our case (Table 1).

4. Discussion

FES is mainly diagnosed by clinical criteria of which our index boy fulfilled 2 major (respiratory distress, cerebral symptoms) and 3 minor criteria (tachycardia, fever, and oliguria) of those established by Gurd

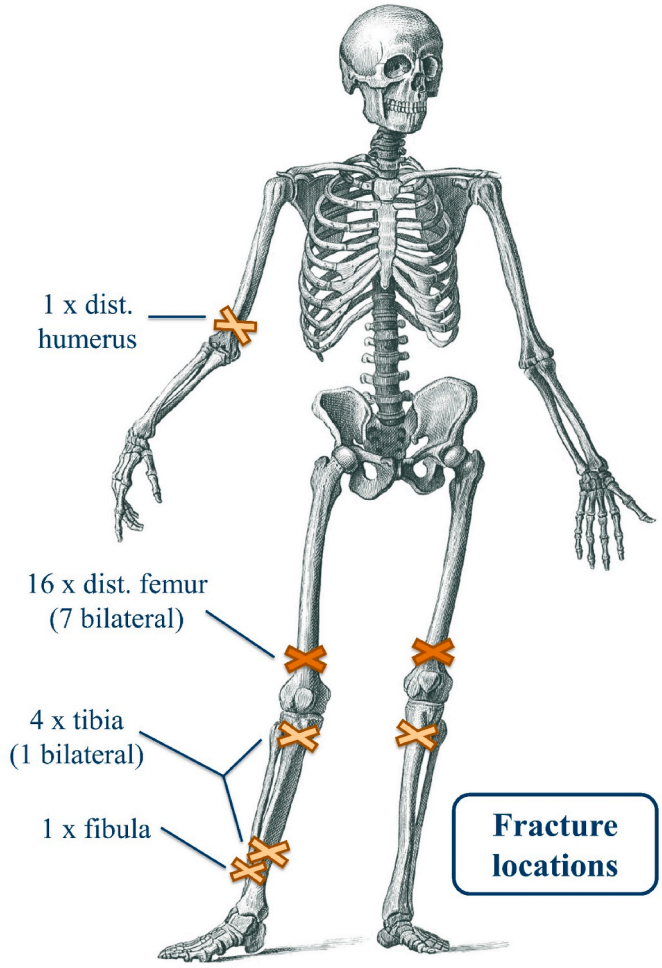

Fig. 5. Fracture locations associated with fat embolism syndrome of affected boys with Duchenne muscle dystrophy from the literature and our case. In most cases femural fractures, particularly of distal femora and bilateral fractures were reported. Dark orange: also present in our patient, light orange: described in the literature. Dist, distal. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

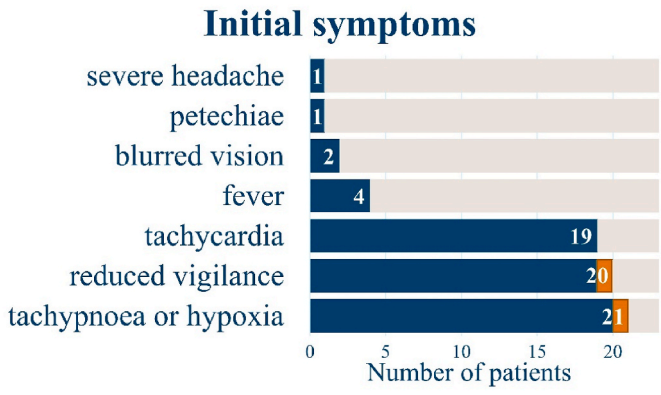

Fig. 6. Presenting symptoms of patients: In 20 patients, neurological symptoms among others constituted the first symptoms at presentation, varying between confusion, agitation, lethargy, seizure, obtundation and unresponsiveness. Orange: symptoms present in our patient, blue: cases from the literature. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

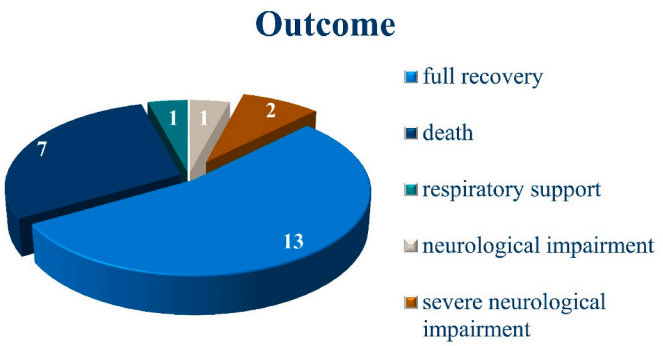

Fig. 7. Outcome after FES in DMD according to literature and our patient. Three individuals had neurological sequelae of varying severity: 2 resulting in either vegetative state or minimally conscious state; orange: including our patient. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

and Wilson in 1974 [25]. In line with these, our review confirmed that respiratory and neurological symptoms were obligate features, in contrast to petechial rash, which was only reported in a minority of cases (29 %) and importantly, was only once a presenting symptom.

Regarding the outcome of FES in DMD, despite overlooking a limited number of published cases, it appears to be less positive than in the normal population. A fatal outcome was described in 30 % of all DMD cases and roughly half of all reported patients did not fully recover, as opposed to the healthy population with long bone fractures, in who a mortality rate of approximately 5 % has been described and full recovery in >90 % [26]. It can be hypothesized that comorbidities such as osteoporosis and prominent adipose tissue remodelling of muscles in adolescent DMD boys are significant risk factors for a more severe course.

In published cases of FES in DMD, fractures were predominantly caused by minor falls from a sitting position, never so far reported in the context of surgery. Strikingly, fractures in our patient remained undetected during surgery and were only revealed after an explicit search was performed thereafter. The finding of recent fractures in both femora were then linked to the soft tissue surgery, although this could not finally be determined. Consequently, elective surgical interventions require careful consideration and special care, particularly in non-ambulant patients with substantial osteoporosis.

Osteopenia or osteoporosis in DMD [27] was described in almost every individual in the literature including our patient. Regarding its treatment, available data was scarce in published cases, mentioning medication with risedronate acid in addition to Vitamin D and Calcium only in 3 patients. We believe there is scope for improvement for early detection and treatment of osteoporosis in the DMD population. In addition, the advent of new dissociative steroids with less detrimental effects on bone health may lead to a reduction of FES in DMD in the future [28].

Despite previous assumptions, the presence of a patent foramen ovale is not a prerequisite for the occurrence of CFE [29], supporting the notion that fat emboli can pass the pulmonary capillaries [5].

Given the unspecific and sometimes temporary occurrence of symptoms in the context of fractures, cases of FES may be masked or even remain undetected in the multimorbid population of adolescent boys with DMD. Our patient initially showed a decline in vigilance post-surgery. We would like to stress the need of a cMRI as the imaging modality of choice for diagnostic work-up. By contrast, CT has been proven to be unsuitable. In various cMRI over a period of 5 months, typical changes of FES became apparent in our patient (Fig. 1) encountering a “starfield pattern”, best depicted on diffusion weighted imaging (DWI) and a “walnut kernel pattern” [30] on susceptibility weighted images (SWI), consisting of monotonous round microbleeds in the subcortical white matter, internal capsule and the corpus callosum.

Table 1
List of the analysed cases (including our case), specifying the author, year of publication, age at FES, further clinical and imaging details.

	Author	Year of publication	Patient	Age at FES	Ambulatory	Osteoporosis/ osteopenia	Steroids	Mechanism of injury	Fracture type	Initial symptoms of FES	Additional symptoms of FES	Neuroimaging	Outcome
1	Pender et al. [14]	1992	1	12	no	NA	no	physical therapy	bilat. dist. femoral	confusion, tachypnoea, tachycardia, blurred vision	confusion, lethargy, generalised seizure; no mec.vent.; pyrexia; elevated ESR	cCT: normal	full recovery after 6 days
2	Vergara Amador et al.[15]	2007	1	14	no	NA	NA	fall	bilat. dist. femoral	tachypnoea, petechiae axilla, somnolent	neurological deterioration; no mec. vent.; retinal emboli, elevated D-dimer	no	full recovery after 10 days
3	McAdam et al. [16]	2012	1	14	no	yes	yes	fall	no	obtunded, tachypnoea, tachycardia	diffuse encephalopathy in EEG; intubation required; pyrexia, hypotension	cCT: normal; cMRI: focal micro-infarcts bilaterally in the basal ganglia, subcortical white matter, internal capsule and right pons	death after 26 h
4			2	14	no	NA	yes	fall	no	obtunded, tachypnoea, tachycardia	intubation required; hypotension, CPR required	NA	death after 36 h
5			3	23	no	yes	yes	fall	no	obtunded, tachypnoea, tachycardia	fluctuating level of conciousness; intubation required; hypotension	cCT: normal	death after 8 h
6			4	14	no	yes	yes	fall	no	obtunded, tachypnoea, tachycardia	intubation required; pyrexia	NA	death after 21 h
7			5	18	no	NA	yes	fall	no	cyanosis, hypoxia, tachycardia	BiPAP required; decreased Hb, headache	NA	full recovery after 11 days
8	Medeiros et al. [17]	2013	1	19	no	yes	yes	fall	bilat. dist. femoral	acute encephalopathy, hypoxia, tachycardia, initial suspicion of seizure	visual changes, loss of conciousness; intubation required; pyrexia, leukocytosis, petechiae, retinal emboli (Purtscher retinopathy)	cMRI: diffuse punctate emboli	persistent vegetative state
9			2	15	yes	yes	yes	fall	bilat. SH II dist. femoral	acute encephalopathy, hypoxia, tachycardia	visual changes; intubation required; leukocytosis, petechiae	cMRI: diffuse punctate emboli	full recovery after 5 days
10			3	14	no	yes	yes	fall	SH II dist. femoral	acute encephalopathy, hypoxia, tachycardia	lethargy; BiPAP required; leukocytosis	cMRI: multifocal cortical and subcortical hyperintense lesions on T2, DWI, for some ADC correlate; 2 weeks later cMRI: Punctate foci on GRE in the right cerebellum	full recovery after 11 days
11			4	20	no	yes	no	fall	femoral	acute encephalopathy, hypoxia, tachycardia	BiPAP required; leukocytosis	NA	full recovery after 5 days
12			5	15	no	yes	yes	fall	SH II dist. femoral	acute encephalopathy,	intubation required; leukocytosis, shock,	NA	full recovery after 12 days

(*continued on next page*)

Table 1 (*continued*)

	Author	Year of publication	Patient	Age at FES	Ambulatory	Osteoporosis/ osteopenia	Steroids	Mechanism of injury	Fracture type	Initial symptoms of FES	Additional symptoms of FES	Neuroimaging	Outcome
13			6	17	no	yes	yes	fall	bilat. dist. femoral	hypoxia, tachycardia acute encephalopathy, hypoxia, tachycardia	ATN, dialysis and CPRx2 required intubation required; leukocytosis	NA	death after 6 h
14			7	16	no	yes	yes	fall	dist. femoral	acute encephalopathy, hypoxia, tachycardia	leukocytosis, CPR required	NA	death after 8 h
15			8	14	no	yes	yes	fall	dist. femoral	acute encephalopathy, hypoxia, tachycardia	hemiparesis, unresponsive; intubation required; leukocytosis, CPR required	NA	death after 8 h
16	Stein et al. [18]	2016	1	15	no	NA	no	fall	prox. tibial	tachycardia, blurred vision	lethargy; BiPAP required; pyrexia, petechia, RNFL infarcts	cMRI: multiple punctate areas of hyperintensity in the deep white matter, thalami, corpus callosum, cerebellum, and pons, consistent with microinfarcts	nocturnal BiPAP (otherwise baseline)
17	Bugnitz et al. [19]	2016	1	13	no	yes	no	fall	bilat. prox. tibial, left dist. femoral	reduced vigilance	minimally responsive, left Babinski sign, right hemiparesis, seizure; BiPAP required; leukocytosis, tachycardia, pyrexia, high ESR	cCT: normal; initial cMRI: DWI: punctate foci of restricted diffusion symmetrically within the centrum semiovale, corona radiata, caudates, putamina, thalami, pons, and cerebellar white matter; 4-days-cMRI: DWI: new areas of restricted diffusion within the cortex and subcortical white matter of the left midtemporal lobe, left parietal lobe, and left occipital lobe	discharged after 20 days with neurological impairment
18	Nation et al. [20]	2018	1	10	no	NA	yes	fall	dist. tibial	tachycardia, pyrexia	coughing, oxygen required; leukocytosis, elevated D-dimer	no	full recovery after 2 days
19	Murphy et al. [21]	2018	1	14	no	NA	yes	transfer	dist. tibial&fibular	confusion, tachycardia, tachypnea, pyrexia	mec. vent. required; pulmonary hypertension, purtscher-like retinopathy, petechial rash, Hb fall, high ESR	cCT: normal	full recovery
20			2	11	yes	NA	yes	fall	SH II dist. femoral	seizure, tachycardia, tachypnea, pyrexia	mec. vent. required; pulmonary hemorrhage, Hb fall, anaemia, high ESR	cMRI: normal	full recovery

(*continued on next page*)

Table 1 (*continued*)

	Author	Year of publication	Patient	Age at FES	Ambulatory	Osteoporosis/ osteopenia	Steroids	Mechanism of injury	Fracture type	Initial symptoms of FES	Additional symptoms of FES	Neuroimaging	Outcome
21	Ernst et al. [22]	2019	1	16	no	NA	NA	fall	femoral, dist. humeral	reduced vigilance, 2h later dyspnoea, pyrexia	soporous, EEG unilateral slowing; HFNC required; thrombocytopenia, elevated CRP and D-dimer, petechiae	cCT: normal; cMRI: DWI: diffusion restrictions bilaterally in the pons, subcortical white matter, and brainstem	full recovery
22	Wihlborg et al. [23]	2019	1	15	no	NA	yes	fall	bilat. SH II dist. femoral	unconsciousness, no pulse, respiration unsteady	seizure; intubation required	cCT: normal; cMRI: multiple punctate changes with diffusion restriction bilaterally in the frontal lobes, parietal and superior in the left occipital lobe in white matter, subcortical and cortical	full recovery after 13 days
23	Abney et al. [24]	2020	1	19	no	yes	yes	fall	SH II dist. femoral	headache, tachycardia, tachypnoe, hypoxia	blurred vision; oxygen required; elevated CRP, Purtscher retinopathy	cCT: normal; cMRI: >20 microinfarcts in the bilateral hemispheres, left corpus callosum, and bilateral basal ganglia	full recovery
24	*our case*	*2023*	*1*	*13*	*no*	*yes*	*no*	*soft tissue surgery*	*bilat. dist. femoral*	*decline in vigilance, respiratory distress*	*increasingly soporous, seizures; intubation required; mydriasis, flush-like exanthema, increase in troponin-T, elevated CRP, pyrexia*	*cMRI: abnormal on day 1, day 4, day 21 and month 5 (Fig. 1)*	*minimally conscious state*

ADC apparent diffusion coefficient, ATN acute tubular necrosis, bilat. bilateral, BIPAP biphasic positive airway pressure, cCT cranial computed tomography, cMRI cranial magnetic resonance imaging, CPR cardio-pulmonary resuscitation, CRP c-reactive protein, dist. distal, DWI diffusion weighted imaging, EEG electroencephalogram, ESR erythrocyte sedimentation rate, FES fat embolism syndrome, Hb hemoglobin, HFNC high flow nasal cannula, GRE gradient echo, h hour, mec. vent. mechanical ventilation, NA information not available, prox. proximal, RNFL Retinal nerve fiber layer, SH II Salter Harris fracture type II.

The MRI pattern with multiple small lesions in the context of reduced vigilance partly resembled changes seen in diffuse axonal injury from traumatic brain damage [31], despite there were a few distinctive features distinguishing both entities. Follow-up- imaging in our patient revealed increasing atrophic and gliotic changes, in line with other reports (Fig. 1) [6].

To our knowledge, no study has investigated the origin of fat in FES in DMD, whether it stems from abundant muscle fat or rather intramedullary fat, being released into the venous system. Risk factors for increased bone marrow fat in our patient were present in the context of osteoporosis, immobility and obesity, according to a study assessing vertebral bone marrow fat content of patients with osteoporosis [32].

Interestingly, our literature search of FES in genetic neuromuscular diseases other than DMD showed none but one case of FES following elective tendon contracture release in a 34-year-old patient with myotonic dystrophy [33], arguing for a specific risk of FES in DMD with osteoporosis in combination with abundant adipose tissue in contrast to other neuromuscular disorders.

Limitations of this study were the variable quality of the reviewed studies and case reports, some of which contained inconsistent and limited information. There is likely an underreporting, especially of milder cases of FES in DMD that impedes the collection of epidemiological data. In addition, included publications emphasised on different aspects and thus, comparison between cases was challenging.

5. Conclusion

Elective surgery in adolescent boys with Duchenne muscular dystrophy should be carefully considered with regard to indication and expected benefit. In the context of osteoporosis and fat replacement of muscles, these patients are at high risk of fat embolism syndrome with relevant neurological and pulmonary sequelae.

6. Bullet points

- Spontaneous unnoticed fractures may occur in DMD due to osteoporosis during elective surgery such as tendon lengthening, further facilitating fat embolism
- The incidence of FES appears to be higher in DMD in the context of fracture, compared with the healthy population, but also in comparison with other genetic neuromuscular conditions
- The clinical outcome after FE in individuals with DMD seems to be less positive than in the general population with highest numbers occurring in adolescence
- The acute imaging pattern on susceptibility-weighted MR-imaging, FLAIR and DWI mimics the clinical picture seen in traumatic diffuse axonal injury with generalised small haemorrhages/lesions cortical and subcortical and clinically results in a diffuse reduction in vigilance with possible coma
- The pathophysiology of FES in DMD is not fully understood and requires further investigation
- Elective surgery in DMD should be extremely carefully considered

Declaration of competing interest

There are no personal financial interests or professional relationships to disclose.

Acknowledgments

The family of our patient has kindly agreed and consented for this case report.

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