Introduction

The management of the polytraumatized patient remains a challenging issue. In recent years many efforts have been made to develop rescue techniques and to promote guidelines for the management of these patients[1].

The term “polytrauma” is mainly used to describe blunt trauma patients whose injuries involve multiple body regions or cavities, compromise patient’s physiology, and potentially cause dysfunction of uninjured organs[1]. Polytrauma is one of the main causes of death in the world. Since young people are frequently involved, trauma is the leading cause of death under the age of 40[2]. Fractures are common findings in polytraumatized patients. These injuries must be considered as wounds of bone and soft tissue, giving rise to stress, pain, and hemorrhage. Patients are at risk of higher morbidity and mortality than the summation of expected morbidity and mortality of each individual injury[3].

Dyspnea in the trauma wards is not a rare occurrence, and it is a usual practice for the respiratory physician to get a call for a patient in acute distress in the trauma wards. The causes of dyspnea can vary in origin and in the gravity of situation it may lead to. There are various causes of dyspnea, secondary to trauma which include direct blunt and penetrating injuries to the thoracic contents and other indirect pulmonary consequences like systemic inflammatory response syndrome (SIRS), Transfusion-

Related Acute Lung Injury (TRALI), fat embolism syndrome, pulmonary embolism (PE) etc. Fat embolism syndrome is by far one of the most common causes, and also the most overlooked cause of dyspnea[4][5].

This syndrome typically affects the young, muscular victims of high-energy trauma, after multiple long bone fractures[6]. The multiple injuries not only initiate the influx of marrow fat into the systemic and pulmonary vasculature, but also trigger a systemic inflammatory response that produces cytokines able of causing pulmonary damage. The number of clinically evident cases of clamant respiratory distress in such a scenario only represents the tip of the iceberg, with a large number of lung injury remaining clinically undetected [7].

- **Definition:**

The term fat embolism (FE) indicates the often asymptomatic presence of fat globules in the lung parenchyma and peripheral circulation after long bone fracture or other major trauma. Fat embolism syndrome (FES) is the serious consequence of fat emboli producing a distinct pattern of clinical symptoms and signs[8].

- **Incidence:**

The precise incidence of fat embolism and fat embolism syndrome are unknown. Fat embolism and milder forms of fat embolism syndrome may go undetected clinically, and in obvious clinical situations the diagnosis is overlooked, this is indicated by the fact that incidence of

clinically detected fat embolism in polytrauma patients was only <1% where as the incidence increased to up to 20% with the help of post mortem examinations[9].

- **Pathogenesis:**

The manifestations of fat embolism are varied and hence the exact pathophysiology of fat embolism is still a controversy. It is not exactly understood why some patients develop fat embolism while others do not. Avikainen et al[10] proposed that it is the intrinsic metabolic changes in certain individuals which turn them susceptible to fat embolism syndrome after a fat embolism episode. The symptoms usually occur within 12 to 72 hours after trauma (especially after fractures), but can occur over a wide range of time of 6 hours to 10 days. The major theories proposed as a mechanism for fat embolism syndrome are:

1) Mechanical theory
2) Chemical theory
3) A combination of both mechanical and biochemical theories
4) Coagulation theory[4].

- **Clinical picture:**

The principal clinical features of fat embolism syndrome are respiratory failure, cerebral dysfunction and skin petechiae. The clinical manifestations develop after trauma when fat globules act as emboli, becoming impacted in the pulmonary microvasculature and other microvascular beds such as in the brain. Embolism begins rather slowly and attains a maximum in about 48 hours[11].

- **Diagnosis:**

Diagnosis is usually made on the basis of clinical findings but biochemical changes may be significant. The most commonly used set of major and minor diagnostic criteria are those published by Gurd[12].

The reliability of these criteria have been questioned and other protocols based more on respiratory features alone have been suggested [13]. A fat embolism index has been suggested as a semi-quantitative means of diagnosing fat embolism syndrome, in which there are seven clinical features each one is given a particular score[14].

- **Prevention:**

Early immobilization of fractures reduces the incidence of fat embolism syndrome and the risk is further reduced by operative correction rather than conservative management. Another strategy to prevent fat embolism syndrome is to limit the elevation in intraosseous pressure during orthopedic procedures, in order to reduce the intravasation of intramedullary fat and other debris[8].

Continuous pulse oximetry (CPOM) monitoring in at-risk patients (i.e., those patients with long bone fractures), may help in detecting desaturations early, allowing early oxygen therapy and possibly steroids, decreasing the chances of hypoxic insult and possible systemic complications of fat embolism syndrome[15].

Recently there is a simple protocol suggested for polytrauma patients which might be valuable in developing

nations. It suggests that patients presenting with a triad of polytrauma, raised initial serum lactate and even a transient episode of hypoxia are at a higher risk for developing fat embolism syndrome/post-traumatic hypoxia?[16].

- **Treatment:**

There is no specific treatment for (FES). The main line of treatment is supportive. Prevention of fat embolism syndrome and early diagnosis with proper management of complications is the cornerstone in managing this condition[15].

Aim of the Study

The aim of the study is to review the fat embolism syndrome in terms of early diagnosis and prevention, aiming to decrease the associated morbidity and mortality in orthopedic patients.

Chapter (I): Historical Review

In classic monograph on fat embolism, Sevitt (1962) wrote: “A hundred years after its first description, there is a lack of agreement and … even confusion as to its frequency, etiology, pathogenesis, clinical significance and its clinical effect”. This report represents an attempt to clarify some of the issues.

Weisz (1974)[13] documentd the early history and refers to the first report, by oxford lower (1669), who injected milk intravenously into experimental animals and found fat droplets in the pulmonary vessels at autopsy. Magendie[17] applied more elaborate studies in the early 19th century and noted that intravenous injection of oil led to mechanical obstruction of small vessels by fat droplets. Virchow[17] reported that injection of intravenous oil produced pulmonary edema. These studies were undertaken without knowing of human FES. The first human case of posttraumatic fat embolism was described by Zenker[17] in 1862 in a patient with a severe crush injury. Fat was found in the pulmonary capillaries at autopsy[18]. In 1873, Bergmann[19] was first to establish the clinical diagnosis of FES. In 1914 Tanton[20] suggested that adequate fracture immobilization could help prevent the condition. In the 1920s, the two theories of fat embolism were put forward which remain valid to this day. Gauss[21] established the

mechanical theory in which he described three conditions for FE to occur: injury to adipose tissue, rupture of veins within the area of injury, and “some mechanism that will cause the passage of free fat into the open ends of blood vessels”. Gauss thought that this mechanism was that blood vessels in bone were strongly bound to their bony channels thus remaining open, unlike veins other sites in the body that tend to collapse and thrombose. Lehman *et al*[22] proposed a biochemical theory to explain FES, hypothesizing those plasma mediators can mobilize fat from body stores and cause it to form large droplets.

Following the introduction of intramedullary nail (IMN) in the 1940s, a number of surgeons were worried about the complication of FE[23][24]. Peltier[23] determined that solid nails caused greater increases in intramedullary pressure (IMP) than hollow nails. Shortly after, he reported a case of fatal FES following intramedullary nailing (IMN) of a closed femur fracture. He advised that prevention of FES should be based on preventing shock, using a hollow nail design, and “driving the nail in slowly with a pause between hammer blows [24].

As with all traumatic conditions, a great deal has been learned about FES during armed conflict. In World War II, the incidence of FES was noted to be approximately 0.8% in a series of 1,000 combat wounds [25]. A study of

110 combat fatalities from the Korean War found that 93% had pulmonary fat at autopsy, but this was only moderate to severe in 19% of cases[26]. However, the authors were not convinced that pulmonary fat embolism could induce pulmonary dysfunction and stated that “serious pulmonary embarrassment may result from embolic fat in occasional cases, but such cases must be quite uncommon”. In Vietnam, technological advances made it possible to diagnose more subtle cases. Collins *et al* [27] noted a high incidence of arterial hypoxemia in 69 wounded soldiers and attributed this to FES after carefully excluding thoracic injuries and hypoventilation as causes of hypoxemia. authors noted a strong association between hypoxemia and femur fractures from high velocity missiles. Cloutier *et al*[28] was able to conduct a prospective study of 50 Vietnam battle casualties and found five classic cases of FES among them.

Chapter (II): Definition

Two terms of interest are fat embolism and fat embolism syndrome. Often used in place of each other, these are not interchangeable[4].

The term fat embolism (FE) indicates the often asymptomatic presence of fat globules in the lung parenchyma and peripheral circulation after long bone fracture or other major trauma. It occurs in approximately all patients who sustain a long bone or a pelvic fracture. Fat embolism syndrome (FES) is the serious consequence of fat emboli producing clinical pattern of symptoms and signs, usually presenting with a classical triad of respiratory distress, cerebral signs and petachiae[11][19].

However, there is no worldwide accepted definition of what constitutes the condition; FES and associated conditions causing respiratory insufficiency arise from pathophysiological processes that are poorly understood, and which are themselves largely diagnoses of exclusion. There is very little high quality evidence on which to base recommendations regarding treatment, which still remains largely empirical and supportive[29]. Intravasation of fat and medullary contents can be demonstrated following over 95% of fractures[30][31] and even bone contusion without fracture[32]. Although most of this material becomes embolized in the pulmonary bed, it seems likely that at least some of this material gains access to the systemic circulation via pulmonary shunts. It is therefore remarkable

that the clinical features of FES itself are so rare, occurring in only 3-4% of patients with long bone fractures. Gurd and Wilson[33] attempted to define the condition on the basis of major and minor criteria to which several other authors have subsequently proposed adaptations and modifications[13][34]. Although Gurd's "cerebral signs" and the presence of a skin rash are apparently relatively trivial after major injury, one should not underestimate the long-term importance of the disabling cognitive defects that may result[35]. However, respiratory insufficiency is clearly the most clinically crucial component of the syndrome in the acute phase. This insufficiency has been recognized under many names: FES, neurogenic pulmonary edema, shock lung, pulmonary failure septic state, and acute lung injury (ALI). More recently, the term acute respiratory distress Syndrome (ARDS) has allowed several of these disparate concepts to be united, and to be defined according to consensus criteria[36]. We now recognize that the stress response to trauma represents a broad spectrum of systemic and pulmonary pathophysiology, of which respiratory insufficiency is just one component, and of which FES in turn is merely one manifestation.

With the exception of rare circumstances where a rash occurs in isolation from respiratory insufficiency, FES should be viewed as being ARDS due to bone trauma, with additional features[29].

- **Causes:**

FES is most common after skeletal injury and it is most likely to occur in patients with multiple long bone and pelvic fractures. Some non-traumatic conditions like diabetes, pancreatitis etc. have been reported to be associated with FES (Table 1)[37].

Table (1): Conditions associated with fat embolism[19].

Trauma related
• Long bone fractures
• Pelvic fractures
• Fracture of other marrow-containing bones
• Orthopedic procedures
• Soft tissue injuries (e.g. chest compression with or without rib fractures)
• Burns
• Liposuction
• Bone marrow harvesting and transplant
Non-trauma related
• Pancreatitis
• Diabetes mellitus
• Osteomyelitis and panniculitis
• Bone tumour lysis
• Steroid therapy
• Sickle cell haemoglobinopathies
• Alcoholic (fatty) liver disease
• Lipid infusion
• Cyclosporine A solvent

Chapter (III): Epidemiology

The precise incidence of FE and FES are unknown. Fat embolism and milder forms of FES may go undetected clinically, and in obvious clinical situation, the diagnosis is overlooked. This is highlighted by the fact that incidence of clinically detected fat embolism was only <1% where as the incidence rose to up to 20% with the help of post mortem examinations[9].

The incidence depends on the bone involved, whether fractures are isolated or multiple, the age of the patient and the gender. It rarely occurs as a result of medical conditions[38]. It is most commonly associated with fractures of long bones and the pelvis, and is more frequent in closed, rather than open, fractures. The incidence increases with the number of fractures involved. Thus, patients with a single long bone fracture have a 1–3% chance of developing the syndrome, but it has been reported in up to 33% of patients with bilateral femoral fractures[39].

Most large clinical series investigating FES involve elective orthopaedic or trauma surgery. The reported clinical incidence tends to be low (Table 2). These studies are striking because the incidence in retrospective long-term reviews is low (< 1%) while prospective studies state a far higher but consistent incidence (11–19%). The incidence of FE at post-mortem is several times more that suspected clinically[40].

Table (2): The incidence and mortality of fat embolism syndrome in recently reported series. transoesophageal echocardiography, TEE. fat embolism syndrome, FES . Modified from[40]

First author	Year	Study design	Incidence (*n*)	Mortality (*n*)
Incidence from clinical series				
Bulger [41]	1997	10 years review of trauma cases	0.9% (27)	7% (2)
Robert [42]	1993	25 years retrospective review	0.26% (20)	20% (4)
Stein [38]	2005	26 years review of trauma cases .928,324,000 hospital admissions overall	0.004% (41000)	
Data from prospective studies				
Fabian [44]	1990	96 consecutive long bone fractures	11% (10)	10% (1)
Kallenbach [51]	1987	Randomised trial of corticosteroids; 82 trauma patients overall	13% (11) overall	Nil
Lindeque [13]	1987	Randomised trial of corticosteroids; 55 trauma patients overall	13% (7) by Gurd criteria 29% (16) by revised criteria	Nil
Chan [25]	1984	80 consecutive trauma patients	8.75% (7) 35% of multiply injured patients	2.5% (2)

Table (2): Continue

First author	Year	Study design	Incidence (*n*)	Mortality (*n*)
Schonfield [14]	1983	Randomised trial of corticosteroids; 62 trauma patients overall	15% (9) overall (No cases in treatment group *n* = 21)	Nil
Myers [52]	1977	100 consecutive trauma patients with long bone fractures	17% (17)	1% (1)
White [43]	2004	7192 trauma patients. An 8 years prospective study	0.5% (36)	
Incidence from TOE studies				
Christie [45]	1995	111 long bone fracture fixations	Emboli seen during 87% (97)	
Pell [46]	1993	24 tibial and femoral nailings	Significant emboli 41% (10), FES 12.5% (3)	4.1% (1)
Incidence from post-mortem data				
Behn [47]	1997	Consecutive post-mortem examinations following death from any cause		17% (92) of all cases
Hiss [49]	1996	Review of 53 blunt trauma deaths		60.4% (32)
Maxeiner [48]	1995	Retrospective analysis of deaths after total hip replacement		0.25% (9)