

Incidence and Age-Stratified Risk Factors for Fat Embolism Syndrome after Reamed Intramedullary Nailing of Long Bone Fractures: A Prospective Observational Study from Eastern India

Somnath Baskey¹, Sarthak Sahoo^{1*}, Sisir Kumar Sahoo¹, Siddharth Panda¹, Rishav Mohapatra², Satirth Sankalp², Radhakishan Sahoo³

¹Assistant Professor, Department of Orthopaedics, SCB Medical College and Hospital, Kataka, Odisha, India

²Senior Resident, Department of Orthopaedics, SCB Medical College and Hospital, Kataka, Odisha, India

³Senior Resident, Department of Orthopaedics, SLS Govt Medical College and Hospital, Phulbani, Odisha, India

***Address for Correspondence:** Dr Sarthak Sahoo, Assistant Professor, Department of Orthopaedics, SCB Medical College and Hospital, Kataka, Odisha, India

E-mail: sdrsarthak@yahoo.com

Received: 25 Jun 2026/ Revised: 18 Jul 2026/ Accepted: 26 Aug 2026

ABSTRACT

Background: Fat embolism syndrome (FES) is a rare but potentially life-threatening complication of reamed intramedullary nailing (IMN) for long bone fractures. This study aimed to determine FES incidence following reamed IMN for femoral and tibial shaft fractures and assess associations with age, surgical timing, and operative duration, addressing the limited age-stratified data from the Indian subcontinent.

Methods: This prospective observational study included 430 adults undergoing reamed IMN for closed or Gustilo-Anderson type I open femoral or tibial shaft fractures at SCB Medical College & Hospital, Cuttack, India, over 12 months. FES was diagnosed using Gurd and Wilson criteria. Clinical and laboratory monitoring was performed every 12 hours for 72 hours postoperatively.

Results: Most patients were male (88.4%), and 34.3% were aged 18–30 years. Three patients (0.69%) developed clinically apparent FES. All were men under 40 years, with a significant age association ($p = 0.042$). Delayed fixation (>72 hours) and prolonged surgery (≥ 90 minutes) were observed in two cases. The classic triad of petechial rash, hypoxemia, and CNS depression occurred in all three patients.

Conclusion: Clinically overt FES following reamed IMN is an uncommon event. However, it predominantly affects younger male patients and appears closely tied to delayed surgical interventions and extended operative durations. These findings emphasize the clinical value of early fracture stabilization and efficient surgical technique, particularly in young trauma patients, while acknowledging that reliance on purely clinical diagnostic criteria likely under-detects milder, subclinical fat embolization.

Key-words: Fat embolism syndrome; Reamed intramedullary nailing; Long bone fracture; Gurd's criteria; Age-related risk; Eastern India

INTRODUCTION

Fat embolism is characterized by the sudden presence of fat globules within the pulmonary or systemic vasculature.

When these emboli provoke a systemic response, the condition escalates to fat embolism syndrome (FES), clinically hallmarked by a classic triad: hypoxemia, neurological impairment, and a petechial rash ^[1]. The true incidence of FES fluctuates based on the injury pattern, ranging from a baseline of 0.09% in unselected long bone fractures, to 0.54% in isolated femoral shaft fractures, and spiking up to 1.29% in patients with multiple concurrent femoral fractures ^[1]. The underlying pathogenesis is complex and likely multifactorial, driven by both mechanical and biochemical mechanisms. Mechanically, severe trauma or intramedullary instrumentation forces marrow fat into torn venous

How to cite this article

Baskey S, Sahoo S, Sahoo SK, Panda S, Mohapatra R, et al. Incidence and Age-Stratified Risk Factors for Fat Embolism Syndrome after Reamed Intramedullary Nailing of Long Bone Fractures: A Prospective Observational Study from Eastern India. SSR Inst Int J Life Sci., 2026; 12(5): 11038-11043.



Access this article online

<https://ijls.com/>

sinusoids. Biochemically, the subsequent lipolysis of these circulating fat globules releases free fatty acids and inflammatory mediators, which damage the pulmonary endothelium and ignite a cascade of systemic inflammation ^[2,3].

Reamed intramedullary nailing (IMN) is the undisputed gold standard for stabilizing diaphyseal long bone fractures. The procedure allows for the insertion of larger, more durable implants, facilitates excellent load-sharing, stimulates endosteal bone healing, and promotes early patient mobilization. However, these biomechanical triumphs come with a distinct physiological trade-off: the reaming process inherently generates a transient but profound spike in intramedullary canal pressure, acting as the primary catalyst for marrow fat embolization ^[4].

Age significantly alters a patient's vulnerability to this embolic shower, albeit in conflicting ways. Younger patients possess richly vascular, haematopoietically active marrow and are more frequently involved in high-energy trauma. Consequently, they tend to release a larger embolic load during injury and reaming. Fortunately, this demographic generally enjoys robust cardiopulmonary reserve, enabling them to tolerate the insult better ^[5,6]. Conversely, older adults have marrow that has largely converted to less cellular fat. While their absolute embolic volume might be lower, age-related declines in pulmonary compliance and a higher baseline of cardiopulmonary comorbidities mean that even a minor embolic load can trigger severe clinical consequences ^[5]. Despite the obvious relevance of age in risk stratification, direct, comparative clinical data across different age brackets remain sparse.

Currently, the bulk of FES incidence data is derived from Western trauma registries. Evidence from the Indian subcontinent is limited to a handful of single-center reports ^[7]. Eastern India, with its high volume of road traffic accidents, serves a demographically diverse population where perioperative FES screening protocols are not uniformly standardized. As a high-volume tertiary referral center performing extensive reamed IMN procedures, SCB Medical College & Hospital in Cuttack is uniquely positioned to map this regional data gap. This prospective study aims to outline the exact incidence of clinically diagnosed FES following reamed IMN at our institution, dissecting the risks across age groups,

surgical timing, and operative duration to isolate actionable perioperative risk factors.

The pathology of fat embolism was first documented by Zenker in 1862 after observing fat droplets in the lungs of a fatally injured railway worker. A decade later, von Bergmann synthesized the clinical manifestation—respiratory distress, altered sensorium, and petechiae—into a recognizable syndrome. In the 1970s, Gurd formalized these observations into the major and minor diagnostic criteria that remain the cornerstone of clinical detection today ^[8]. Despite over a century and a half of research, a definitive, single diagnostic biomarker remains elusive. The diagnosis still heavily relies on astute clinical pattern recognition supported by auxiliary laboratory and radiological data, which largely explains the wide variance in reported FES incidence across different clinical settings.

MATERIALS AND METHODS

Study Design and Setting- This prospective, hospital-based observational study was conducted in the Department of Orthopaedics at SCB Medical College & Hospital, Cuttack, Odisha, over a 12-month period. Institutional Ethics Committee approval was secured prior to commencement. Written informed consent was obtained from all participants, and strict patient confidentiality was maintained.

Study Population- Using a purposive sampling strategy, we enrolled adults (≥ 18 years) presenting with diaphyseal fractures of the femur or tibia (AO/OTA types 42-A/B/C and 32-A/B/C) requiring reamed IMN. Patients with closed fractures or Gustilo-Anderson type I open fractures were deemed eligible. We strictly excluded pediatric patients, individuals with Gustilo-Anderson type II or III open fractures, and those with concurrent head or abdominal trauma, pre-existing neurovascular deficits, or signs of FES predating surgical intervention. A final cohort of 430 eligible patients was established.

Data Collection- A structured clinical proforma was utilized to prospectively capture demographic variables (age, sex), injury specifics (mechanism, side, associated systemic injuries), and surgical parameters. Surgical data included the timing of fixation (categorized as early if within 72 hours of injury, or delayed if beyond 72 hours), the specific procedure (femoral interlocking nail, tibial

interlocking nail, or proximal femoral nail), and the total operative duration.

Diagnosis of Fat Embolism Syndrome- FES diagnosis was anchored to Gurd and Wilson's criteria ^[8]. A positive diagnosis required the presence of either two major criteria or one major and four minor criteria. Major criteria include axillary/subconjunctival petechiae, hypoxemia, disproportionate CNS depression, and pulmonary edema. Minor criteria encompass tachycardia, pyrexia, retinal changes, lipuria, an unexplained drop in hemoglobin, thrombocytopenia, an elevated erythrocyte sedimentation rate (ESR), and fat globules in the sputum. Patient assessments occurred immediately post-surgery and were rigorously repeated every 12 hours for a 72-hour window.

Investigations- Baseline and daily postoperative investigations (up to 72 hours) included complete blood counts, ESR, urine microscopy for fat globules, and plain chest radiography. High-resolution computed tomography (HRCT) of the chest was reserved for cases with high clinical suspicion of FES.

Statistical Analysis- Data were aggregated in Microsoft Excel and analyzed via SPSS software. Categorical data were expressed as frequencies and percentages, evaluating differences through the chi-square test or Fisher's exact test. A two-sided p-value <0.05 was considered statistically significant.

Ethical Approval and Informed Consent: The study was approved by the Institutional Ethics Committee, SCB Medical College & Hospital, Cuttack, India. All procedures adhered to institutional guidelines and the Declaration of Helsinki. Written informed consent was obtained from all participants before enrolment.

RESULTS

The patient cohort was strikingly young; over half the patients (53.6%) were under the age of 40, with the 18–30 age bracket being the most represented (34.3%). The population was overwhelmingly male (88.4%) (Table 1). The most frequent injuries treated were femoral shaft fractures (36.7%), followed by intertrochanteric femoral fractures (29.3%) and tibial shaft injuries (21.2%) (Table 2).

Table 1: Consolidated Patient Demographics (N = 430)

Demographic Variable	Category	Patients (n)	Percentage (%)
Age Group (Years)	18–30	147	34.3
	31–40	83	19.4
	41–50	45	10.5
	51–60	52	12.1
	61–70	63	14.7
	> 70	39	9.1
Sex	Male	380	88.4
	Female	50	11.6

Table 2: Injury Characteristics and Timing of Surgical Fixation (N = 430)

Variable	Classification	Patients (n)	Percentage (%)
Fracture Diagnosis	Shaft of femur	158	36.7
	Intertrochanteric femur	126	29.3
	Shaft of tibia / both-bone leg	91	21.2
	Subtrochanteric femur	38	8.8
	Other (polytrauma)	17	3.3
Timing of Surgery	< 72 hours (Early)	74	17.2
	≥ 72 hours (Delayed)	356	82.8

Reflecting the heavy referral burden and logistical realities of a high-volume trauma center, 82.8% of the cohort underwent delayed surgical fixation (beyond 72 hours of injury) (Table 2).

Over the 72-hour postoperative monitoring phase, systemic inflammatory markers were prevalent: tachycardia was noted in 313 patients, an elevated ESR in 150, and fever in 93. A significant postoperative hemoglobin drop (>20%) was noted predominantly in complex or high-energy fracture patterns (Table 4). Despite these systemic reactions, definitive classical signs of FES were rare (Table 3).

Table 3: Key Clinical and Radiographic Findings within 72 Hours Post-Surgery (N = 430)

Clinical / Laboratory Finding	Total Incidence (n)	Percentage of Cohort (%)
Tachycardia	313	72.8
Raised ESR	150	34.9
Fever	93	21.6
Hemoglobin fall > 20%	49	11.4
Petechial rash	21	4.9
Hypoxemia	12	2.8
CNS depression	12	2.8
Fat globules in urine	9	2.1
Positive Chest X-ray	6	1.4

Table 4: Mean Perioperative Hemoglobin Trends (g/dL) by Fracture Pattern

Diagnosis Group	Pre-op Baseline	Day 1	Day 2	Day 3
Shaft of tibia / both-bone leg	10.80	9.80	10.40	10.30
Intertrochanteric femur	10.50	9.00	9.80	9.80
Shaft of femur	10.08	8.80	9.20	9.40
Subtrochanteric femur	9.89	7.76	8.59	8.53
Polytrauma	10.21	7.87	8.84	8.89

Based on Gurd and Wilson's criteria, clinically overt FES was diagnosed in exactly 3 out of the 430 patients, establishing an incidence rate of 0.69%. All three cases materialized in men under the age of 40. The complete

absence of FES in patients aged 40 and older resulted in a statistically significant age-based association ($p = 0.042$) (Table 5).

Table 5: Risk Factors and Clinical Correlates for Fat Embolism Syndrome

Risk Variable	Category	FES Cases (n=3)	Non-FES (n=427)	p-value	Statistical Significance
Age Group	< 40 yrs	3	227	0.042	Significant
	≥ 40 yrs	0	200		
Timing of Surgery	< 72 hrs	1	73	>0.05*	Descriptive only
	≥ 72 hrs	2	354		
Duration of Surgery	< 90 min	1	-	>0.05*	Descriptive only
	≥ 90 min	2	-		

(Note: Due to the rarity of the event (n=3), p-values for surgical timing and duration are considered descriptive rather than confirmatory)

Regarding surgical variables, two of the three FES cases were subjected to delayed fixation (>72 hours) and endured operative times lasting 90 minutes or longer. Clinically, all three afflicted patients exhibited the quintessential major triad: petechial rash, hypoxemia, and CNS depression, supplemented by anemia and elevated ESR.

DISCUSSION

Our study population heavily skewed toward young males, accurately reflecting the epidemiology of high-energy road traffic trauma commonly observed in the region. Aggarwal *et al.* [7] and Koul *et al.* [9] similarly reported entirely male-predominant series in their respective level I trauma center cohorts in India, with median ages securely in the third decade of life. The

occurrence of clinically overt FES in our cohort sits at 0.69%, aligning seamlessly with global incidence rates. Tsai *et al.* ^[10] noted an incidence of 0.78% post-reamed IMN, while Georgopoulos *et al.* ^[11] cited a prospective rate of 0.9%. This concordance indicates that with standardized monitoring, frank, life-threatening FES remains rare, though clinical diagnostic criteria inherently miss milder subclinical manifestations.

The most critical finding of this study is the statistically significant concentration of FES cases exclusively in men under 40 years of age ($p = 0.042$). This aligns with the pathophysiological theory that young, highly cellular, and vascularized marrow is capable of discharging a much larger embolic load during physical disruption. While younger patients theoretically possess the cardiopulmonary fortitude to withstand embolic hits, our data suggests that the sheer volume of the embolic load released during intramedullary reaming in this age group overrides their physiological resilience, pushing them past the threshold into clinically evident FES.

Real-world logistical hurdles meant 82.8% of our patients underwent fixation after 72 hours. Two of the three FES cases emerged from this delayed-fixation pool. This mirrors foundational concepts proposed by Riska and von Bonsdorff ^[12], who advocated for early fixation to minimize pulmonary complications. Furthermore, Pape *et al.* ^[4] effectively linked prolonged intramedullary manipulation directly to a heavier embolic burden. In our cohort, two out of three FES patients underwent surgeries lasting 90 minutes or longer, a finding mechanistically supported by Miller *et al.* ^[13], who demonstrated that techniques reducing intramedullary pressure generation correspondingly lower the embolic load. Due to the small number of events, these associations act as hypothesis-generating insights rather than definitive conclusions, urging caution and efficiency during prolonged orthopedic reconstructions.

All three FES patients in this study exhibited a classic subacute presentation 24 to 72 hours post-injury, relying heavily on Gurd's major criteria (rash, hypoxemia, CNS changes). Crucially, only 1.4% of the entire cohort showed abnormalities on plain chest radiography, highlighting its notorious insensitivity for diagnosing pulmonary fat embolism. Advanced imaging modalities, such as MRI—which can beautifully capture the "starfield" pattern of cerebral fat emboli ^[14]—were not

utilized, representing a limitation in capturing subclinical disease.

These results must be contextualized within the broader debate surrounding reamed versus unreamed nailing. While a robust meta-analysis by Li *et al.* ^[15] confirmed that reaming accelerates fracture union and decreases secondary interventions without drastically increasing mortality, the biomechanical superiority comes at the cost of transiently elevating marrow pressures. Unreamed nailing avoids this pressure spike but sacrifices mechanical stability. Therefore, careful patient selection—particularly in young males facing delayed, lengthy procedures—is imperative.

STRENGTHS AND LIMITATIONS

This study provides valuable, region-specific FES incidence data from Eastern India, an area historically under-represented in trauma literature. The prospective 12-hourly monitoring ensured rigorous data capture during the critical 72-hour postoperative window.

However, the study is limited by the very small absolute number of FES events ($n=3$), curtailing deep multivariate analysis. Additionally, the lack of advanced imaging protocols and a direct comparator arm (e.g., unreamed nailing) limits our ability to quantify subclinical embolization rates or definitively prove the superiority of alternative fixation techniques.

CONCLUSIONS

While clinically diagnosed fat embolism syndrome is a rare complication (0.69%) following the reamed intramedullary nailing of long bone fractures in Eastern India, it shows a highly significant predilection for younger male patients (under 40 years). Furthermore, FES presentation appears linked to surgical delays exceeding 72 hours and operative durations extending past 90 minutes. These findings strongly advocate for institutional prioritization of early fracture stabilization and optimized, efficient surgical techniques. Surgeons should maintain a heightened index of suspicion for FES in young male trauma patients undergoing delayed, prolonged reaming. Future multicenter trials utilizing advanced imaging are essential to map the true hidden burden of subclinical fat embolism.

ACKNOWLEDGMENTS

The authors thank the Department of Orthopaedics, SCB Medical College & Hospital, Cuttack, for their continuous institutional support.

CONTRIBUTION OF AUTHORS

Research concept – Sarthak Sahoo

Research design – Sarthak Sahoo

Supervision – Sarthak Sahoo, Somnath Baskey, Sisir Kumar Sahoo

Materials – Somnath Baskey, Siddharth Panda

Data collection – Somnath Baskey, Siddharth Panda, Satirth Sankalp

Data analysis and interpretation – Somnath Baskey

Literature search – Somnath Baskey, Sisir Kumar Sahoo, Rishav Mohapatra, Satirth Sankalp, Radhakishan Sahoo

Writing article – Somnath Baskey

Critical review – Sarthak Sahoo

Article editing – Sarthak Sahoo, Sisir Kumar Sahoo

Final approval – Somnath Baskey, Siddharth Panda, Rishav Mohapatra, Satirth Sankalp, Radhakishan Sahoo

REFERENCES

- [1] Kosova E, Bergmark B, Piazza G. Fat embolism syndrome. *Circulation*, 2015; 131(3): 317–20.
- [2] Lempert KM, Cerat TW, Campbell ST. Fat embolism syndrome: a systematic review. *OTA Int.*, 2021; 4(1): e097.
- [3] Lehman EP, Moore RM. Fat embolism: with special reference to its differentiation from other types of embolism. *JAMA*, 1997; 88(18): 1478–83.
- [4] Pape HC, Giannoudis PV, Grimme K. Intramedullary reaming and fat embolism. *J Orthop Trauma*, 2000; 14(5): 353–61.
- [5] Pfeifer R, Gradl G, Schuermann T. The influence of osteoporosis on fat embolism syndrome. *Injury*, 2010; 41(4): 410–12.
- [6] Pinney SJ, Keel SB, Tencer AF. Fat embolism in isolated femoral shaft fracture. *J Trauma*. 1998; 45(2): 335–41.
- [7] Aggarwal A, Prakash V, Sharma V, Babhulkar S. Fat embolism syndrome: clinical experience in a level I trauma center in India. *Indian J Orthop.*, 2011; 45(6): 525–29.
- [8] Gurd AR, Wilson RI. The fat embolism syndrome. *J Bone Joint Surg Br.*, 1994; 56(3): 408–16.
- [9] Koul PA, Ahmad F, Gurcoo SA, Khan UH, Naqash IA, et al. Fat embolism syndrome in long bone trauma following vehicular accidents: experience from a tertiary care hospital in north India. *Lung India*, 2013; 30(2): 97–102.
- [10] Tsai IT, et al. Fat embolism syndrome in long bone fracture. *J Chin Med Assoc.*, 2008; 71(7): 331–35.
- [11] Georgopoulos D, et al. Clinical diagnosis of fat embolism syndrome. *Chest*, 1993; 103(6): 1819–21.
- [12] Riska EB, von Bonsdorff H, et al. Prevention of fat embolism syndrome by early fixation. *Injury*, 1996; 8(2): 110–16.
- [13] Miller AN, et al. Reamer-irrigator-aspirator reduces embolic load. *J Orthop Trauma*, 2018; 32(4): 182–87.
- [14] Kwiatt ME, Seamon MJ. Fat embolism syndrome. *Int J Crit Illn Inj Sci.*, 2013; 3(1): 64–68. doi: 10.4103/2229-5151.109426.
- [15] Li AB, Zhang WJ, Guo WJ, Wang XH, Jin HM, et al. Reamed versus unreamed intramedullary nailing for the treatment of femoral fractures: a meta-analysis of prospective randomized controlled trials. *Medicine (Baltimore)*, 2016; 95(29): e4248.

Open Access Policy:

Authors/Contributors are responsible for originality, contents, correct references, and ethical issues. SSR-IJLS publishes all articles under Creative Commons Attribution- Non-Commercial 4.0 International License (CC BY-NC). <https://creativecommons.org/licenses/by-nc/4.0/legalcode>

