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Floating knees: variables affecting bone union and functional outcomes: a retrospective study of 72 cases

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Abstract – *Introduction*: Floating knee involves concomitant and ipsilateral fractures of the femur and tibia, sometimes associated with a patellar fracture. Complications are common, and functional outcomes are often poor. This study aimed to evaluate bone healing and to identify factors influencing nonunion and functional results. *Methods*: This retrospective study included 72 knees, with a mean follow-up of 4.5 years. The primary outcome was bone union. Neurological, vascular and meniscoligamentous injuries were analyzed. Follow-up parameters were clinical, radiological and functional, including the Karlström and Olerud score. *Results*: At least one fracture was open in 69% of cases. Mean time to union was 10.5 months for the femur, 7.5 months for the tibia, and 4.4 months for the patella. Nonunion occurred in 68% of femoral fractures, 57% of tibial fractures, and 42% of patellar fractures. Open fractures and tibial vascular injuries were significant predictors of nonunion. Meniscoligamentous injuries were diagnosed in 32% of cases and were more frequent with increasing Ran stage ($p = 0.004$). Surgical site infection occurred in 30.6% of cases and was significantly associated with open fractures ($p < 0.001$). Functional outcomes worsened with increasing Ran stage, meniscoligamentous injuries, open fractures, and infection. *Conclusion*: Floating knee injuries are characterized by prolonged healing, high rates of nonunion and infection, and limited functional outcomes.

Key words: Floating knee, Bone union, Nonunion, Meniscoligamentous injury, Complications, Functional outcomes.

Introduction

Concomitant ipsilateral fractures of the femur and tibia define the floating knee, a rare but severe injury, typically occurring in the context of high-energy polytrauma. These injuries are associated with substantial morbidity, with reported mortality rates ranging from 5% to 15% and immediate amputation rates reaching up to 25% [1]. In addition to life-threatening complications, they are characterized by high rates of fracture-related complications, with reported nonunion rates ranging from 4% to 28% for the femur and from 3% to 36% for the tibia [2–6], as well as infection rates up to 20–30% in some series [5, 7, 8].

Several classification systems have been proposed to describe floating knee injuries, reflecting fracture location and complexity. The most widely used classification by Fraser focuses on diaphyseal and articular involvement, whereas more recent systems, such as the Ran classification, incorporate articular extension and patellar fractures (Figure 1) [9]. Further refinements have been proposed to include soft-tissue and meniscoligamentous lesions, highlighting their prognostic importance [2]. Increasing fracture complexity has consistently been associated with higher rates of complications, including nonunion, infection, stiffness and post-traumatic osteoarthritis [9–12].

In addition to bony injuries, associated soft-tissue and meniscoligamentous lesions play a critical role in prognosis. These injuries, reported in up to 30–70% of cases depending on the diagnostic strategy, are frequently underdiagnosed and may lead to chronic instability, stiffness, and poor functional outcomes [11–13]. Although intramedullary nailing combined with early rehabilitation is generally associated with improved healing and functional recovery, this approach is not always feasible in polytrauma patients, particularly in the presence of severe soft-tissue damage or vascular injury [1, 14]. As a result, treatment strategies remain heterogeneous, and outcomes vary across studies.

Despite growing interest in this injury pattern, the available literature is mainly composed of small retrospective series with limited follow-up. Most studies focus on isolated aspects of the

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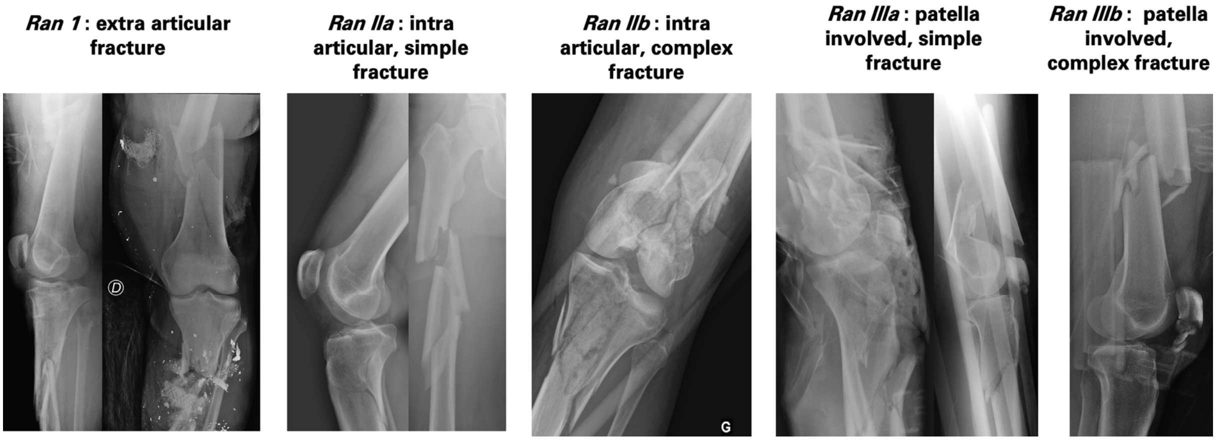

Figure 1. Classification of floating knees by Ran.

injury, such as fracture healing, ligamentous lesions, or functional outcomes, but rarely provide a comprehensive analysis integrating all the parameters. Moreover, the prognostic impact of associated meniscoligamentous injuries remains insufficiently characterized.

Therefore, the primary objective of this study was to identify variables affecting bone union and risk factors for non-union. The secondary objective was to evaluate the impact of articular involvement, meniscoligamentous lesions and postoperative complications on clinical, radiological and functional outcomes.

Materials and methods

Population

This retrospective bicentric cohort included patients with floating knee between January 2008 and December 2021.

The initial database included 105 floating knees in 101 patients.

Exclusion criteria were associated limb injuries likely to dominate functional prognosis, patterns not fitting the Ran classification, age <16 or >65 years, periprosthetic, physeal, recurrent or pathological fractures.

After exclusion, 72 floating knees in 70 patients were included. 40 (60%) were treated at the Edouard Herriot Hospital and 29 (40%) at the Lyon Sud Hospital Center (Figure 2). There was 58 men and 12 women, with a sex ratio of 4.8:1. Mean follow-up was 53.9 months [9–188]. Mean age at time of injury was 34 years [16–62]. In this young population, 50 (71.4%) patients had no medical background. 26 (37.1%) were active smokers.

Injury characteristics

Fractures were classified according to Ran [9] and Gustilo and Anderson [15]. Neurological, vascular, meniscoligamentous and associated injuries were studied.

Postoperatively, there was no standardized rehabilitation protocol.

Ran type 1 was the most frequent pattern (Table 1). Patellar fractures (Ran 3 type) were present in 13 cases (18.1%). Comminution was present in 12 (16.7%) femoral fractures and 21 (29.2 %) tibial fractures. Segmental fractures were observed in 1 (1.4%) femur and 6 (8.3%) tibias. Open fractures involved femur in 33 cases (45.8%), tibia in 36 (50%) and patella in 8 (61.5%). At least one fracture was open in 50 floating knees (69.4%).

Initial surgical management commonly involved damage-control strategies, with 29 (40.3%) femoral external fixations and 36 (50%) tibial external fixations. Following initial stabilization, 26 femoral fractures (36.1%) and 39 tibial fractures (54.2%) underwent definitive osteosynthesis. In Ran type 3 knees, 7 patellar fractures (53.8%) were managed non-operatively, 5 (38.5%) underwent fixation, and 1 (7.7%) underwent patellectomy.

Average delay between initial and definitive surgery was 16.4 [1–60] days for femur and 38.4 [3–210] days for tibia. The average time to surgical management was 15.7 days [2–84] for patella.

9 (12.5%) associated arterial injuries were found. 4 (44.4%) required emergent surgical repair. Neurological injuries were present in 12 cases (16.7%), mostly involving the common fibular nerve. 17 (23.6%) associated osteoarticular injuries of the limb were recorded.

Only 13 (18.6%) patients had an isolated floating knee. The remaining 57 (81.4%) patients were polytraumatized.

There were 23 (31.9%) cases of meniscoligamentous injuries. 9 (39.1%) were single ligament injuries. 8 (34.8%) were multiligament injuries. There were 2 (8.7%) isolated meniscal injuries, 2 (8.7%) patellar tendon avulsions, and 2 (8.7%) meniscoligamentous injuries. Mean diagnosis delay was 11.2 months [0–167]. Diagnosis methods included 10 clinical exams (43.5%), 6 intraoperative findings (26.1%), 5 MRI (21.7%), 1 CT (4.3%) and 1 radiograph (4.3%). 8 injuries (34.8%) were surgically treated at a mean of 29.2 days post-injury, including two treated concomitantly with fracture fixation.

Meniscoligamentous lesions were significantly associated with increasing Ran stage (Cochran–Armitage, $p < 0.05$) and

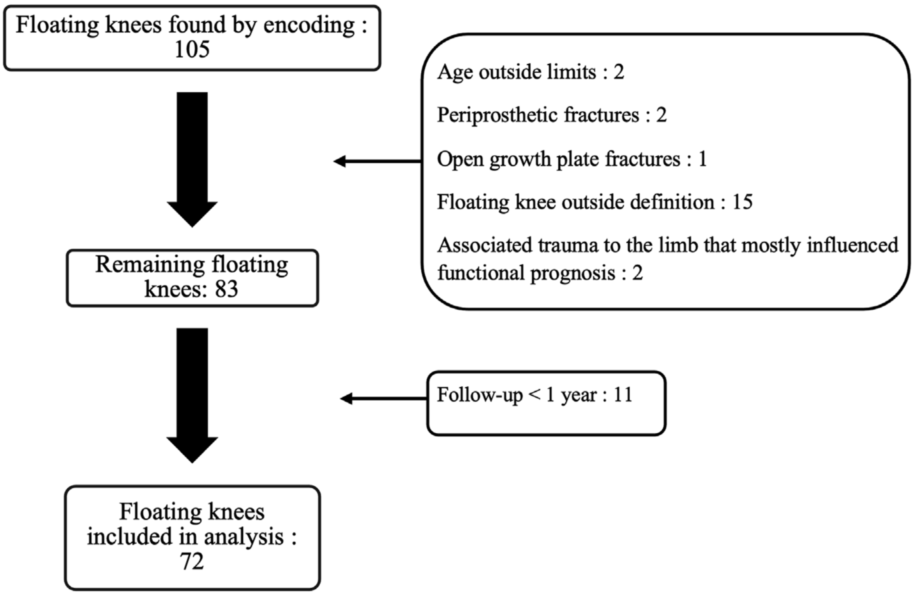

Figure 2. Flowchart.

Table 1. Distribution of floating knees according to Ran's classification and skin condition (Gustilo and Anderson classification).

Classifications	Subtypes	Floating knee *n* (%)	Femur *n* (%)	Tibia *n* (%)	Patella *n* (%)
Ran 1 (extra-articular)	–	35 (48.6%)	–	–	–
Ran 2 (intra-articular)	2a	13 (18.1%)	–	–	–
	2b	11 (15.3%)	–	–	–
Ran 3 (intra-articular + patella)	3a	3 (4.2%)	–	–	–
	3b	10 (13.9%)	–	–	–
Comminution			12 (16.7 %)	21 (29.2 %)	10 (13.9%)
Segmental			1 (1.4 %)	6 (8.3 %)	–
Closed fracture	–	–	39 (54.2%)	36 (50%)	5 (38.5%)
Open fracture	–	–	33 (45.8%)	36 (50%)	8 (61.5%)
Gustilo I	–	–	3 (4.2%)	6 (8.3%)	/
Gustilo II	–	–	24 (33.3%)	16 (22.2%)	8 (61.5%)
Gustilo III	IIIA	–	4 (5.6%)	4 (5.6%)	/
	IIIB	–	2 (2.8%)	5 (6.9%)	/
	IIIC	–	/	5 (6.9%)	/

with chronic instability (Fisher, $p < 0.05$), but not with postoperative stiffness ($p = 0.71$).

Bone healing

Union was achieved when 3 out of 4 cortices were fused radiographically.

Nonunion was defined as the absence of radiographic healing at six months, based on incomplete cortical bridging (fewer than 3 out of 4 cortices) [7, 16]. It could be septic or mechanical.

Complications

Muscular, cutaneous, septic, neurological, osteoarticular, and general complications were recorded. Treatment failure was defined as inability to preserve the native knee.

Clinical, radiological and functional outcomes

Clinical and radiographic examination of the knee at the last follow-up was recorded.

Functional parameters were assessed as well as the Karlström and Olerud score (KOS) [17].

Statistical analysis

The analyses were performed using GPL RStudio 1.0 software (Posit.Software, PBC). Descriptive statistics summarized the characteristics of the groups and subgroups.

Quantitative data were expressed as means if they followed a normal distribution, otherwise as medians.

For nominal qualitative variables, Fisher's test was used to analyze associations. When the analysis involved an increasing nominal variable or an ordinal variable, Cochran–Armitage's trend test was used. When both variables were ordinal, the association was evaluated using Kendall's tau-b coefficient. For sample sizes of less than 5, the results were verified by a fixed-margin permutation test for the Cochran–Armitage test and/or tau-b. For binary outcomes based on quantitative variables, logistic regressions were used.

The significance threshold was $p = 0.05$.

Results

Bone healing

Mean time union was 10.5 [2–84] months for femur, 7.5 months [2–24] for tibia, and 4.4 months [1–9] for patella.

There were 49 (68.1%) femoral nonunions including 4 septic and 45 mechanical, compared with 41 (56.9%) in tibia, including 11 septic and 30 mechanical. Patellar healing was complicated by 5 mechanical nonunions (41.7%). 33 (45.8%) patients developed nonunion of the femur and tibia. Only 14 floating knees (19.4%) healed without nonunion. Overall, 56 knees (77.8%) developed at least one nonunion.

Significant predictors of nonunion included open fractures of the femur and tibia and tibial vascular injury. No significant predictor was identified for patellar nonunion (Table 2).

Table 2. Risk factors for nonunion.

Factor investigated	Femoral nonunion	Tibial nonunion
Joint fracture (Ran 2a, 2b, 3a, 3b)	No	No
Open fracture	Yes ($p = 0.01$)	Yes ($p = 0.03$)
Comminution	No	No
Segmental fracture	No	No
Vascular lesions	No	Yes ($p = 0.001$)
Meniscoligamentous injury	No	No
Exofixation	No	No
Type of osteosynthesis	No	No
Age	No	No
Active smoking	No	No

Complications

46 (56.9%) floating knees developed at least one complication.

4 (5.6%) acute compartment syndromes occurred.

12 (16.7%) cases presented with cutaneous complications, 11 (29.3%) requiring reconstruction surgery.

Surgical site infection occurred in 22 knees (30.6%), diagnosed at a mean of 22.5 months (1–78). Infection was significantly associated with open fractures of the femur ($p < 0.001$) and tibia ($p < 0.001$) at Fisher's exact test.

31 (43.1%) floating knees had at least one osteoarticular or material-related complication. 10 (13.9%) developed stiffness (<90° flexion at 3 months). No significant association was found between Ran classification and osteoarticular complications.

6 systemic complications were recorded, including 2 (2.8%) fat embolisms and 4 (5.6%) venous thromboembolic events. No death occurred.

7 (9.7%) knees could not be saved. Among these, there were 2 (2.8%) femorotibial arthrodeses, 3 (4.2%) resection prothesis and 2 (2.8%) amputations. All involved open and articular fractures.

Follow-up outcomes

Clinical data were available for 66 patients. 28 (42.2%) had a normal range of motion. 11 (15.3%) had instability.

Radiographically, 48.6% developed knee osteoarthritis at the last follow-up. The incidence of osteoarthritis increased significantly with Ran stage ($p < 0.001$).

KOS was available for 67 patients. Most patients had poor scores (20 patients, 29.9%), 14 (20.9%) were acceptable, 17 (25.4%) were good and 16 (23.9%) were excellent. Predictors of poor functional outcome included meniscoligamentous injuries ($p < 0.05$), open fracture ($p < 0.001$), infection ($p < 0.001$), and higher Ran stage (Kendall tau-b, $p < 0.001$).

Discussion

Main findings

Nonunion rates were particularly high (68.1% femur, 56.9% tibia, 41.7% patella), with open fractures and tibial vascular injuries as the main predictors. Mean union time was 10.5 months for the femur, 7.5 months for the tibia, and 4.4 months for the patella.

For meniscoligamentous injuries (31.9%), the mean time to diagnosis was 11.2 months. Their frequency increased significantly with fracture severity. Functionally, patients with this type of injury had significantly poorer KOS results and more chronic instability.

The frequency of osteoarthritis increased significantly with stages of Ran classification, showing a prognostic impact of articular and comminuted injuries and patellar involvement.

Infections (30.6%) were significantly more frequent in open fractures.

Overall functional outcomes were mostly poor. A significant correlation was found between poor outcomes and severity according to Ran, open fractures, meniscoligamentous injuries and infection.

Comparison with the literature

Our nonunion rates were higher than those reported in the literature, which range from 4% to 28% for the femur and from 3% to 36% for the tibia [2–6]. This discrepancy likely reflects the severity of injury patterns in our cohort, characterized by a high proportion of comminuted, articular and open fractures (Table 1). In addition to fracture severity and soft-tissue damage, the frequent use of staged fixation strategies within a damage control framework may have contributed to these results [14, 18]. Although often necessary in polytrauma patients, this approach may lead to delayed definitive fixation and suboptimal mechanical conditions for bone healing. Furthermore, the presence of associated vascular injuries, particularly affecting the tibia, may have further compromised the local biological environment.

Table 3. Comparison with literature.

Author, year of publication	Number of cases	Classification	Average follow-up (months)	Nonunion rate (%)	Time to union (months)	Meniscoligamentous injury (%)	Infection (%)	Karlström & Olerud's score
Ostrum [1], 2000	20	Winquist	18.5	/	Femur: 3.6 Tibia: 5.7	/	5%	88% good or excellent 6% acceptable 6% poor
Rethnam [13], 2009	29	Blake and Mc Bryde	24	/	Femur: extra articular : 4.8 10% acceptable intra articular : 5.6 Tibia : extra articular : 5.2 intra articular : 4.2	14%	/	52% excellent 34% good 3% poor
Hegazy [4], 2011	15	Fraser	23.5	/	Femur : 3.7 Tibia : 5.8	/	7%	53% excellent 27% good 13% acceptable 1% poor
Feron [16], 2015	172	Fraser	34	Total : 21%	/	6%	/	17% excellent 37% good 24% acceptable 12,5% poor
Shahzad [8], 2015	65	Fraser	6	Femur : 11% Tibia : 14% Total : 12%	/	/	Femur : 17% Tibia : 20%	25% excellent 40% good 25% acceptable 11% poor
Kulkarni [7], 2018	90	Fraser, Ran	36	Femur : 27% Tibia : 32%	Femur : 10.5 Tibia : 9.5	/	11%	24% excellent 29% good 27% acceptable 12% poor
Ethiraj [18], 2022	46	Ran	12	/	Femur : - DCO : 11 - ETC : 9 Tibia : - DCO : 10 - ETC : 9	/	22%	DCO : 15% excellent 40% good 35% acceptable 10% poor ETC: 29% excellent 62% good 9,5% acceptable 0 poor
Meccariello [2], 2024	168	Fraser, Ran	89	Femur : 22% Tibia : 65% Femur & tibia : 13%	/	79%	7%	29% excellent 35% good 23% acceptable 14% poor
Our study	72	Ran	54	Femur : 68% Tibia : 57% Femur & tibia : 46%	Femur : 10.5 Tibia : 7.5	32%	31%	24% excellent 25% good 21% acceptable 30% poor

DCO: damage control orthopedics; ETC : early total care.

Among studies, reported healing times also vary widely, depending on fracture complexity and treatment strategies. Shorter times are generally observed in selected populations treated with intramedullary nailing [1, 19] (Table 3), typically involving younger patients and excluding more complex fracture patterns as Ran types 2 and 3, which have consistently been associated with prolonged healing in several series [2, 4, 20, 21].

Differences in reported healing times across studies may also reflect variability in the assessment of bone union and lack of standardized definition of nonunion across studies. We defined nonunion as the absence of radiographic healing at six months, based on the criterion of incomplete cortical bridging, which is consistent with definitions used in previous studies [7, 16]. However, other authors rely on the absence of radiological progression over time, or use longer postoperative thresholds up to 9 months, before establishing the diagnosis [5]. This heterogeneity in definitions should be taken into account when comparing results across studies.

Regarding meniscoligamentous injuries, delayed diagnosis is known to be responsible for poor functional outcomes [22]. Liu et al. [12] systematically performed knee testing after osteosynthesis as well as diagnostic arthroscopy. Such an invasive approach resulted in high reported lesion rate (70%), with likely overdiagnosis, and the functional impact was not studied. This approach is favored by many authors instead of preoperative MRI, which is often not available or inappropriate in a damage-control context. It also avoids postoperative MRI, which is often limited by osteosynthesis artefacts [13, 23].

Meccariello et al. [2] used the same approach and reported 78.6% meniscoligamentous injuries. They studied the predictive value of a new prognostic classification that included meniscoligamentous injuries, and concluded that the KOS was better correlated with this classification than with Ran classification.

Articular involvement in fractures is usually associated with stiffness. Although this association was not significant in our cohort, it has been reported by Kulkarni et al. and Kurkowski et al., who also identified tibial open fractures, extensor mechanism injuries and reoperations as risk factors [7, 24]. The impact of patellar fractures in our results could not be demonstrated due to lack of statistical power and has only been studied in a few series [2, 9, 24]. Ran et al. [9] reported an incidence of 25% patellar fractures, of which 29% developed stiffness. The classification proposed by Meccariello et al. [2] was statistically predictive of a worsened KOS according to the different stages.

Regarding surgical site infections, their incidence in our cohort aligns with the upper range of published data [5, 8].

Regarding functional outcomes, many studies reported mainly good to excellent results [5, 16] (Table 3). The high rates of nonunion and infection in our series, as well as the absence of systematic evaluation of meniscoligamentous injuries, may partly explain our results. The very elevated proportion of Ran type 1 floating knees in some studies [5, 16] can also explain their better functional scores.

Strengths and limitations

The strength of our study lies in its sample size. Although it is not the largest series published, it allows for subgroup analyses, some of which yielded significant results using statistical analyses adapted to small sample sizes. The average follow-up period of 53.9 months, or approximately 4.5 years, is one of the longest found in the literature [3, 5, 6, 25], but does not allow for the evaluation of long-term post-traumatic osteoarthritis.

This study has several limitations that should be acknowledged. First, its retrospective design inherently exposes it to selection bias, information bias related to incomplete or missing data, and potential confounding factors, with no possibility of randomization or control over treatment allocation. Second, although relatively large for such a rare condition, the sample size may still be insufficient to provide adequate statistical power for all subgroup analyses.

In addition, the absence of a standardized rehabilitation protocol across patients may have influenced both bone healing and functional outcomes. The bicentric design, involving variability in surgical strategies, timing of definitive fixation, and postoperative management, as well as the multiplicity of surgeons, further contributed to heterogeneity in patient care. Moreover, the long inclusion period, spanning more than a decade, likely reflects changes in surgical techniques, implants, and overall trauma management, which may have impacted the results.

Finally, the heterogeneity in injury patterns, particularly the high proportion of open and severe fractures, may limit the generalizability of our findings and partly explain the high rates of nonunion and complications observed in this cohort.

In line with recent publications, the study of extensor apparatus injuries, systematic screening for meniscoligamentous lesions, and the relevance of rehabilitation protocols must be further analyzed [2, 24].

Conclusion

This study highlights the importance of early and meticulous management of skin and vascular lesions to limit their impact on bone union. Skin opening and articular injuries make debridement and anatomical reduction essential. Meniscoligamentous injuries must be identified early in the management process. Follow-up must be prolonged to detect instability, stiffness, and knee osteoarthritis. Functional outcomes depend on multiple parameters whose prognostic value has been demonstrated.

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Conflicts of interest

Authors 1, 2, and 3 declare that they have no relevant financial or non-financial interests to report.

Author 4: Consultant for Dedienne Santé,

Author 5: Consultant for InterView Partners,

Author 6: Consultant for Stryker, DePuy,

Author 7: Royalties from Adler Ortho; consultant for Orthofix, SERF and Noraker.

Data availability statement

Data originate from the Hospices Civils de Lyon medical information systems and cannot be publicly released for ethical reasons.

Author contribution statement

Author 1: data collection, data analysis, statistical analysis,
Authors 2, 3: data collection,
Authors 4, 5: study conception, manuscript review,
Author 6: manuscript review,
Author 7: data analysis, study design, manuscript review.

Ethics approval

All procedures were performed in accordance with the ethical standards of the institutional and/or national research committee, the 1964 Helsinki declaration and its later amendments, or comparable ethical standards. Data collection and analysis were carried out in accordance with MR004 Reference Methodology from the CNIL (2242371v0) obtained on February 16, 2026. The study was registered and filed on the Health Data Hub website.

Informed consent

Written informed consent was obtained from all patients.

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