ISSN 2241-4347

Volume 76 · Issue 1 · 2025

ΑΟΤΗ

Acta Orthopaedica et Traumatologica Hellenica

Official Journal of the
HELLENIC ASSOCIATION OF ORTHOPAEDIC SURGERY AND TRAUMATOLOGY
Athens Academy Award 2004

Acta Orthopaedica et Traumatologica Hellenica

HELLENIC ASSOCIATION
OF ORTHOPAEDIC SURGERY
AND TRAUMATOLOGY

Published by: ZITA MEDICAL MANAGEMENT S.A.
Omirou 29, Peta Saronikou, Attica, Greece, 190 01,
tel.: +30 22994 40962,
E-mail: info@zita-management.gr

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References examples:

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Mavrogenis AF, Altsitzioglou P, Tsukamoto S, Errani C. Biopsy Techniques for Musculoskeletal Tumors: Basic Principles and Specialized Techniques. Curr Oncol. 2024;31(2):900-917. doi: 10.3390/curroncol31020067.

Sun J, Mavrogenis AF, Scarlat MM. The growth of scientific publications in 2020: a bibliometric analysis based on the number of publications, keywords, and citations in orthopaedic surgery. Int Orthop. 2021;45(8):1905-1910. doi: 10.1007/s00264-021-05171-6.

Kolovos S, Sioutis S, Polyzou M, Papakonstantinou ME, Karampikas V, Altsitzioglou P, Serenidis D, Koulalis D, Papagelopoulos PJ, Mavrogenis AF. The risk of DDH between breech and cephalic-delivered neonates using Graf ultrasonography. Eur J Orthop Surg Traumatol. 2024;34(2):1103-1109. doi: 10.1007/s00590-023-03770-0.

Book chapters:

Mavrogenis AF, Antoniadou T, Dimopoulos L, Filippiadis D, Kelekis A. Metastasis (Chapter 26). In: Textbook of Musculoskeletal Disorders. Vincenzo Denaro, Umile Giuseppe Longo (Eds). © Springer Nature. 2023. ISBN 978-3-031-20986-4.

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Writing for Acta Orthopaedica et Traumatologica Hellenica (AOTH)

Andreas F. Mavrogenis

Editor-in-Chief, Acta Orthopaedica et Traumatologica Hellenica (AOTH)

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Materials and Methods (approximately 1000–1500 words)

The section should start with the Materials in brevity and clarity. An example could read as follows: *"We present ….. patients admitted and treated at the authors' institution with …… from 2000 to 2024. There were … men and … women with a mean age of … years (range, ….. years)"*. These two sentences provide almost all basic demographic information of the materials of the study. Follow-up is materials and should be provided here; the same for loss to follow-up including the reasons for the loss. Clinical reports must state inclusion and exclusion criteria and whether the series is consecutive or selected; if selected, criteria for selection should be stated. These should inform the readers for any sources of bias.

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Results (approximately 500 words)

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The authors should provide which group/method/ analysis is more significant compared to another and parenthetically state the p-value immediately after the comparative terms. Provide the actual p-values instead of p-values greater or lesser than 0.05. Parenthetic reference to all figures and tables enables easier interpretation of the data. Avoid too many numeral data in tables because it complicates and fatigues reading.

Discussion (approximately 1500-3000 words)

The Discussion should start with a restatement of the problem or question in brief for emphasis, followed by the study findings and a synthesis of the comparison and the author's new data to arrive at conclusions.

The second paragraph should be the limitations. I prefer the readers should be informed early for the limitations of the study. Failure to explore the limitations suggests the authors either do not know or choose to ignore them, potentially misleading the reader.

In the next paragraphs the authors should discuss their findings in comparison to the literature. They should synthesize their data with that in the literature. The text should be formatted in paragraphs respective to the study questions/ answers. Appropriate and quality studies should be used. Generally, many of these reports will include those cited at the Introduction section. A Table that summarizes the results of the most important published related studies would be useful here (refer to papers with similar tables for the format).

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should be avoided. Statements such as "need for further research" or "need for future studies" should be avoided because they underpower the study.

References

Choose quality references, and read the most important papers in full text; approximately 25% of the references used in the references list of a paper are actually read by the authors when writing the paper. References should be accurate and up-to-date. Electronically available citations should be preferred; abstracts and submitted articles (pending publication), newsletters, proceedings, and meetings syllabus should not be used because many in these categories ultimately do not pass peer review because it is not possible to be traced and cited. Use citations from the journal to submit your paper; this will gain the Editor that you are aware of the journal; it will increase the visibility of the paper and the impact of the journal.

Figures and Tables

Figures and tables should complement not duplicate material in the text. They present information that would be difficult to describe in text form. Well-written papers contain one or two tables or figures for every study question/purpose posed in the Introduction. The legends should be explanatory and concise; what the figure/table show.

References

1. Brand RA. Writing for clinical orthopaedics and related research. Clin Orthop Relat Res. 2008;466(1):239-47. doi: 10.1007/s11999-007-0038-x.
2. Mavrogenis AF, Auffret Babak I, Caton JH. Writing for SICOT-J. SICOT J. 2021;7:E1. doi: 10.1051/sicotj/2021042.
3. Mavrogenis AF, Scarlat MM. Writing for "International Orthopaedics": authorship, fraud, and ethical concerns. Int Orthop. 2021 Oct;45(10):2461-2464. doi: 10.1007/s00264-021-05226-8.

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Contents

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Letter from the Editor

Can a fracture liaison service (FLS) be successfully established in Greece?

Efthymios Iliopoulos[1], Georgios Drosos[1]

[1] *Metabolic Disease and Fragility Fractures Unit, Academic Orthopaedic Department of General University Hospital of Alexandroupolis, Democritus University of Thrace, Alexandroupolis, Greece*

Osteoporosis is a metabolic disease that primarily affects the elderly population in most countries across the globe, with its incidence rising significantly over the past decades. This condition leads to a significantly increased risk of fragility fractures, which can lead to several complications and even death.[1] Greece faces the same challenge, with projections indicating a substantial rise in osteoporosis and fragility fractures the coming years.[2] In particular, the growing incidence of fragility fractures and especially the hip fractures threaten to overwhelm the local health care systems, leading to increased complications, mortality rates and costs.[3] Treating these patients presents numerous challenges for health care professionals, who have to address not only the fracture but also co-existing conditions such as multiple comorbidities, sarcopenia, malnutrition and frequent falls.[4]

With the view of improving the health care services provided for these patients, the fragility fracture network (FFN) global has divided the these challenges into four pillars, helping to articulate and organise these patients' management. The first pillar focuses on the multi-disciplinary approach and the orthogeriatric management of these patients. The second pillar focuses on the rehabilitation and the aftercare of these patients, with the view to improve their independence and quality of life. The third pillar focuses on the secondary prevention of a new fragility fracture and the fourth pillar focuses on the national collaborations and change of local policies.[5]

Fracture Liaison Service (FLS)

It has been proven that a fragility fracture significantly increases the risk of a new fragility fracture especially the first two years.[6,7] To prevent a second fracture, proactive measures should be taken, especially for patients who have already sustained a fragility fracture and received treatment by a health care provider. These measures include diagnosing and treating osteoporosis, as well as reducing falls risk by addressing factors such as visual impairment, home safety modifications, and medication adjustments. This is a difficult task that requires a collaborative effort among healthcare professionals from various disciplines. Therefore, in many countries, such coordinated efforts have struggled to succeed, leading to a significant treatment gap.[6,8]

The Fracture Liaison Service (FLS) is designed to systematically implement secondary prevention for all patients with fragility fractures.[9] The implementation of such service has been proven to significantly reduce the risk of subsequent fractures.[10] A key factor in the success of FLS is the effective recruitment of eligible patients, typically initiated through local fragility fracture registries. Once enrolled, the FLS team - comprising doctors, nurses, physiotherapists, occupational therapists, dietitians, and other specialists - works to prevent further fractures through a personalized approach. This includes the

osteoporosis medication and compliance, implementing fall prevention strategies (such as home modifications, vision correction, neurological disease management, and reducing polypharmacy), and addressing sarcopenia.[11,12]

The FLS in Greece

In Greece, only few sporadic attempts have been made to establish a fracture liaison service.[13,14] Key issues identified in these studies include a low recruitment rate, ranging between 30-55%, and the extremely poor follow-up rate of less that 20% in both studies.[13,14] Data from the newly established Greek National Fragility Hip Fracture Registry further highlight the problem, revealing that the majority of patients (>60%) do not receive osteoporosis medication upon discharge from the acute care hospitals.[15] This reflects a general lack of awareness among hospital doctors regarding secondary prevention. Additionally, the absence of incentives, experience, and motivation among healthcare professionals in the Greek public sector exacerbates the issue. An effective FLS requires time and resources -challenges that cannot be overcome through personal effort and commitment alone, which, at present, remain the primary driving forces behind such initiatives.[16]

In conclusion, secondary prevention of the fragility fractures is crucial factor in enhancing the quality of the healthcare services provided to our patients while reducing the financial burden of their treatment. Establishing an effective fracture liaison service should be a primary focus in achieving these goals. Successful implementation requires collaboration among a diverse team of healthcare professionals, alongside administrators and government authorities. With a well-structured and strategic plan, this initiative can become a reality. The recent establishment of the Greek fragility hip fracture registry, along with other ongoing projects by FFN Greece, offer a promising foundation for the eventual implementation of a Greek Fracture Liaison Service (FLS).

Review

Greek fragility hip fracture registry 2024 annual report

Efthymios Iliopoulos[1], Theodoros Tosounidis[2], Reichan Molla Moustafa[1], Athanasia Charmpi[3], Fotios Tilkidis[4], Ioannis Daskalakis[2], Dimitra Melissaridou[5], Maria Sentona[6], Georgios Graikos[7], Androniki Kyprianou[8], Irini Tatani[3], Ioannis Gkiatas[4], Byron Chalidis[7], Ioannis Papachristos[8], Christianna Zidrou[6], Olga Savvidou[5], Georgios Drosos[1]

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Abstract

The Greek fragility hip fracture registry has been established since 2022 with the valuable involvement of many orthopaedic departments across the country. Its presence has significantly helped to create an enthusiastic team that aims to improve the health services that these patients receive in our country. The registry has helped to depict the present situation of the services that the patients with a fragility hip fracture receive in the Greek hospitals and also establish the first benchmarking of our system.

The present study is the annual report of the year 2024, the second full year that the registry runs. During this year two new orthopaedic departments have been added to the registry

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team, helping to raise the numbers of the collected patients to almost one thousand. The use of the minimum common data set, as suggested by the FFN global network, helped the Greek registry to collect important demographic, pre-injury status, fragility hip fracture, surgery and rehabilitation data for these patients. The length of stay of the patients during 2024 remained at the 10 days but the 30-day mortality has been slightly raised to 14.5% for this year.

Keywords

Hip fracture audit; national registry; Greece, fragility fracture; neck of femur fracture

Introduction

The incidence of fragility fractures is increasing the last years. Especially the hip fractures pose a significant burden in the health care systems across the globe. Registries have been used in many countries in order to document the current situation in the respective countries and also identify specific systemic weaknesses, which can help to improve the health services provided to these patients. It has been reported that large scale implementation of such registries help to improve the timing to surgery, the 30-day mortality, and even the quality of life of these patients.[1,2] For this reason many national registries have been established across the globe and especially across Europe.[3]

In Greece a pilot national hip fracture registry has been established from 2022 after an initiative of the Greek fragility fracture network (FFN Gr).[4] The aim of the present study is to present the annual report of the second year of its implementation. The Greek fragility hip fracture registry uses the minimum common data set as proposed by the global fragility fracture network with the addition of the 30-day mortality of the patients.[5]

2024 Annual Report

Involved Departments

The Greek Fragility hip fracture registry, during 2024, continued functioning for the second year. During this period two new Orthopaedic departments joined the group of Greek Registry. These departments are the First Academic Orthopaedic Department of Aristotle University of Thessaloniki, Papanikolaou General University Hospital of Thessaloniki and the Trauma & Orthopaedics Department of Tzaneio General Hospital of Piraeus. These raised the number of the involved departments to nine. Furthermore, four more Orthopaedic departments from across the county expressed their willingness to participate to this project and started the processes for their inclusion (Figure 1).

Data Collected

Data from a total of 998 patients were collected during 2024 raising the total number of the included patients in the Greek registry to 2003. The mean age of the patients during 2024 was 82.44 ±8.3years similar to the registry average of 82.35 ±8.4 years. The majority of the patients were female (69.2%) which is slightly lower than to the registry average (70.6%) (Figure 2).

Most entries this year were made by the Patras University Hospital followed by the Papanikolaou University General hospital of Thessaloniki (Figure 3).

The summer was the season with most fragility hip fracture admissions, with June being the busiest month of 2024 (Figures 4 and 5).

Patients' pre-injury status

The mean ASA grade of the fragility hip fracture patients was 2.85 ±0.9 this year, slight higher than the registry average (2.72 ±0.87). The cognitive status of the majority of the patients was normal (69%) but a total of 12% was found to have positive tests for cognitive impairment at admission without having an already diagnosed dementia (Figure 6).

The majority of the patients were living in their own house (95%) and were independent prior to the injury with a total of 68% being able to mobilize without any aids or with only one stick outside their house (Figures 7 and 8).

Figure 1. Geographic map of Greece where the involved departments are annotated with a star.

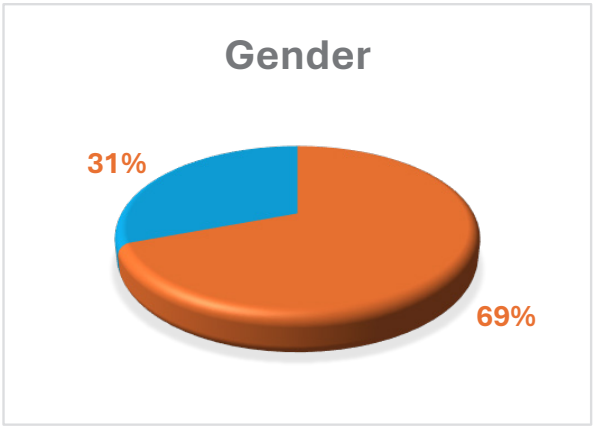

Figure 2. Gender distribution of the 2024 cohort.

Fracture type information

The Greek elderly patients sustain most frequerntly intertrochanteric type of hip fragility fracture, and this was the case again for 2024 (Table 1; Figures 9 and10).

Surgical Procedure Information

Surgery was elected as not suitable for 6.5% of the patients, who followed conservative management. Table 2 summarises the types of operations performed (table 2). The rest received an operation, which was performed under spinal anesthesia for the majority of the patients (75%) (Figure 11). Unfortunately, only for the 34% of the patients the operation performed in a timely manner (within 48 hours from admission), illuminating for another time the significant problem of lack of theatre time and anesthesiologists in the Greek Hospitals (Figure 12).

Hospitalization

The length of stay during 2024 for the fragility hip fracture patients was 10.4 ±8 days, similar to the average of the Greek registry which is 10.6 ±8.2 days. The in hospital mortality was 4.5%. More than half of the patients (62%) were mobilized off bed the first post-operative day (Figure 13), while 16% developed a new pressure sore during their hospitalization (Figure 14). Internal medicine doctors supported their orthopaedic colleagues at the treatment of 61% of these patients, emphasizing the lack of specialized Ortho-geriatricians in Greece.

Discharge Data

Most of the patients were discharged home (58%) after their admission for the fragility hip fracture, while the rehabilitation center as exit destination raised this year to 32% (Figure 15).

Only 16.2% of the patients discharged from hospital with information about starting, continuing or changing their anti-osteoporotic medication, with the majority remaining without secondary prevention attempt (Figure 16).

Follow-up Data

The 30-day mortality for 2024 was 14.5%, slightly raised than 2023, raising the total registry 30-day mortality to 10.6%. Note that during Autumn the 30-day mortality was lower than the rest of the seasons (Figure 17).

Discussion

During 2024 the fragility hip fracture registry kept rising adding almost 1000 new patients in the database. This fact helped the registry to be established and also can provide with more reliable results about the situa-

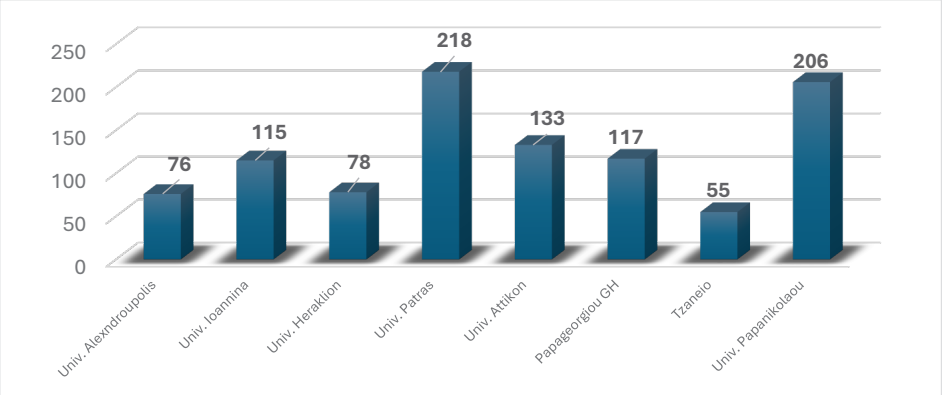

Figure 3. *2024 entries from the different hospitals involved*

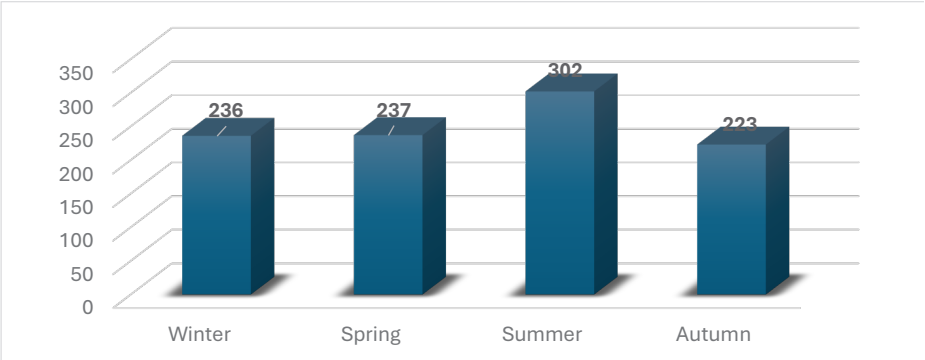

Figure 4. *2024 entries as distributed across the year*

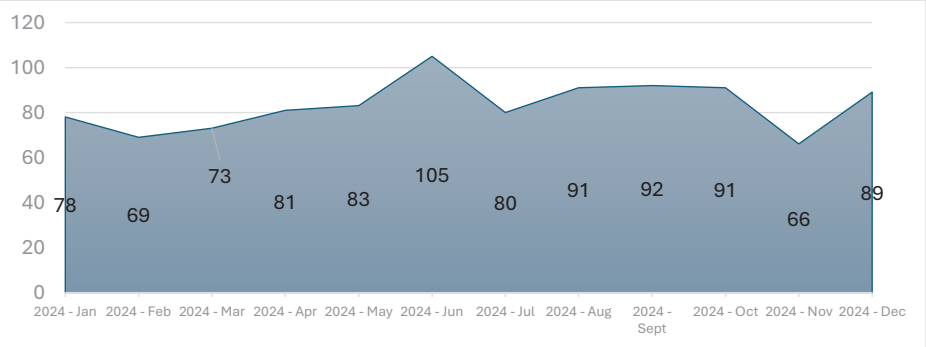

Figure 5. *2024 entries as distributed across the months of the year*

tion in the Greek health care system. Significant findings of this year's report are the unique feature of the Greek population having more extra-capsular fractures than intra-capsular ones as well as the high incidence of patients living at their own home before the injury. Interestingly in all the European hip fracture registries the intra-capsular fractures are more frequent than the extra-capsular ones. The only countries that this feature is reversed is in Greece and in Spain, illuminating a possible difference in the mechanism of these injuries or individual profile of these patients in these two Mediterranean countries.[3] Another mostly cultural unique feature of the Greek population is the increased percentage of patients living in their own

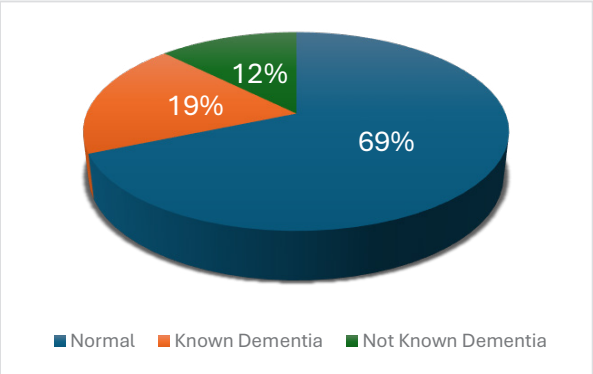

Figure 6. *Cognitive status of the cohort.*

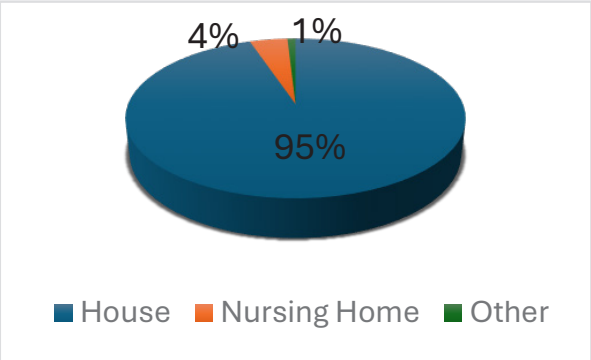

Figure 7. *Patients' pre-injury residence*

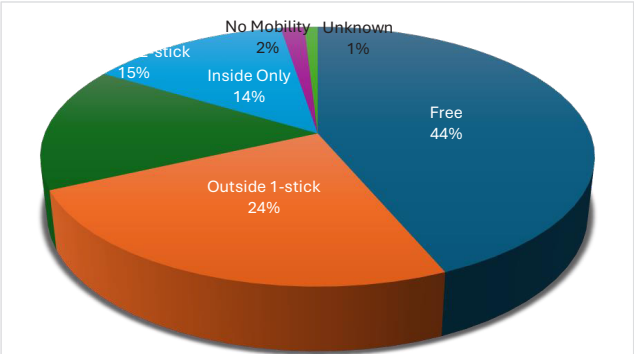

Figure 8. *Patients' pre-injury mobility status*

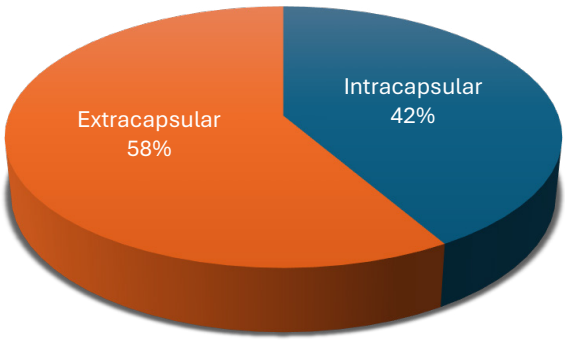

Figure 9. *Fragility hip fracture types in 2024*

Table 1 Distribution of fracture types in the cohort

Fracture Type	No	%
Intracapsular Undisplaced	28	2.8
Intracapsular Displaced	387	38.9
Intertrochanteric	520	52.3
Subtrochanteric	44	4.4
Other	16	1.6

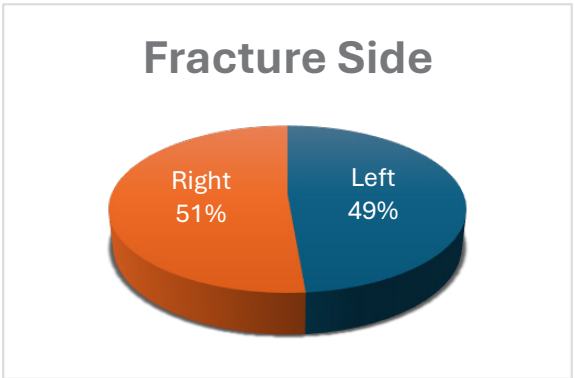

Figure 10. *Fracture side percentage in 2024*

house before the injury. In Greece this percentage is reported to reach 95%, which is the highest in Europe, with only Italy running close to this with 90%.[3]

The mortality rate of the Greek cohort was raised to 14.5% during 2024, comparing the previous year, which was significantly lower.[4] Despite that it is still remains in levels comparable to the other European countries.[3] This fact can be possibly explained by the fact that only 30% of the patients are being operated within 48 hours from admission, which is proven to be an important factor for these patients. Other countries have managed to achieve percentages of operations in a timely manner over 80%, with only Italy and Spain scoring relatively low in this feature (65% and 48%, respectively).[3]

The present fragility hip fracture registry is the first

Table 2. Types of operations performed during 2024		
Type of Operation	**No**	**%**
Conservative Management	64	6.7
Cannulated Hip Screws	5	0.5
Dynamic Hip Screw	1	0.1
IM nail	510	53.7
Hip Hemiarthroplasty	321	33.8
Total Hip Arthroplasty	27	2.8
Other	22	2.3

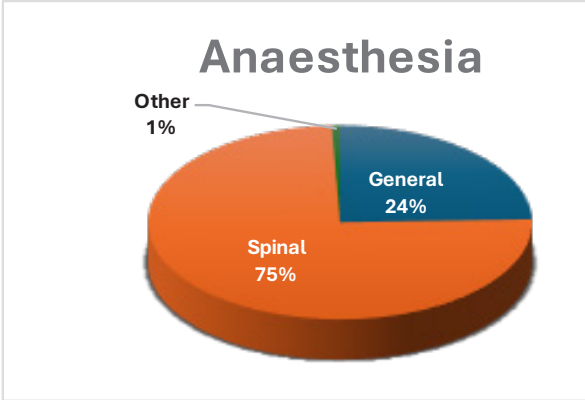

Figure 11. *Type of anaesthesia*

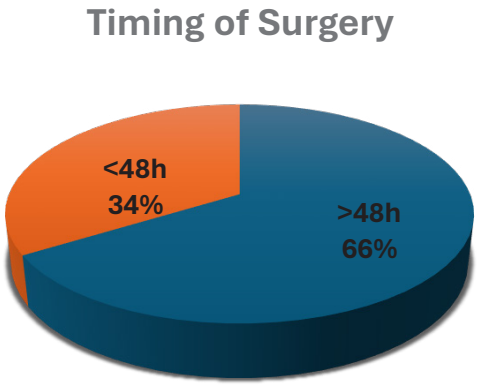

Figure 12. *Time to surgery distribution across the cohort.*

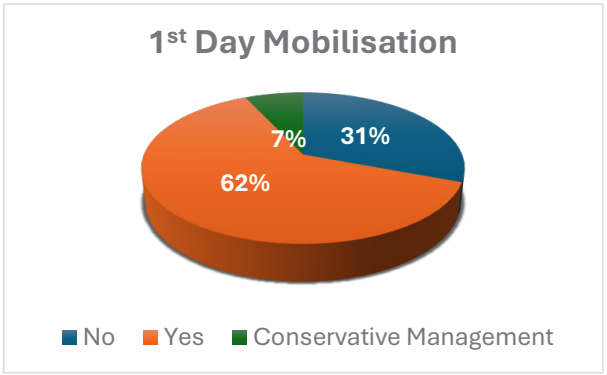

Figure 13. *Percentage of patients managed to be mobilised doff bed during the 1st post-operative day.*

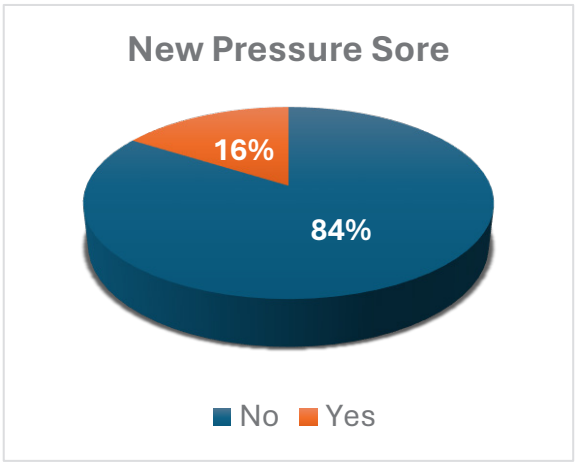

Figure 14. *Percentage of patients developed a new pressure sore during the acute hospital admission*

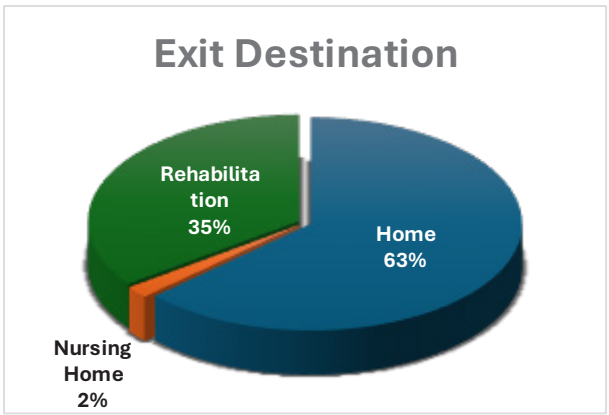

Figure 15. *Destination of discharge.*

such multicentre study in the Greece. Earlier single centre reports, illuminate similar mortality rates in central and northern Greece.[6,7] The development and establishment of this national registry hopefully will be the stepping stone for developing an effective fracture liaison service nationwide (FLS), which as mentioned in previous studies lacks significantly in the country.[8–10] Such national registry provides the health care professional across the country with the tools to investigate the present status of the Greek patients and

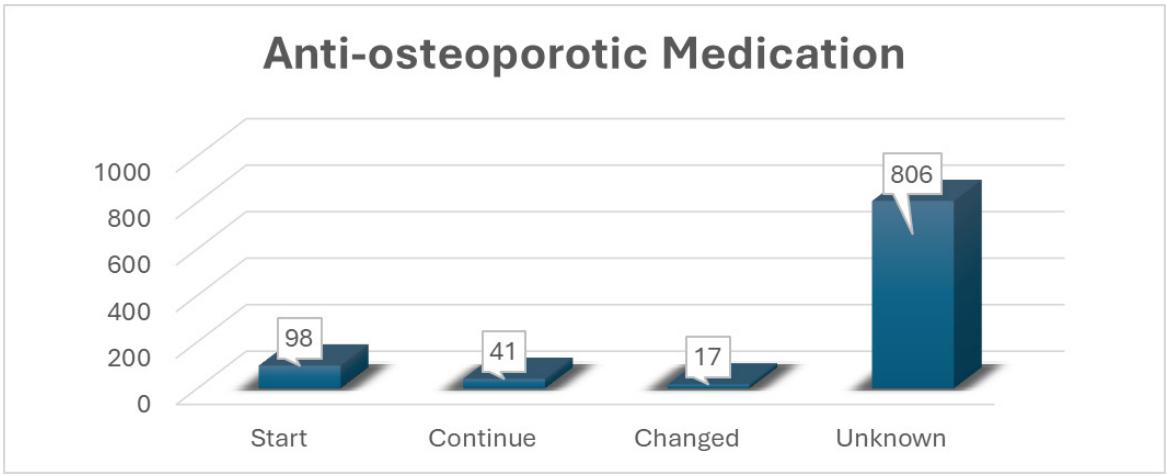

Figure 16. *Secondary prevention during first admission*

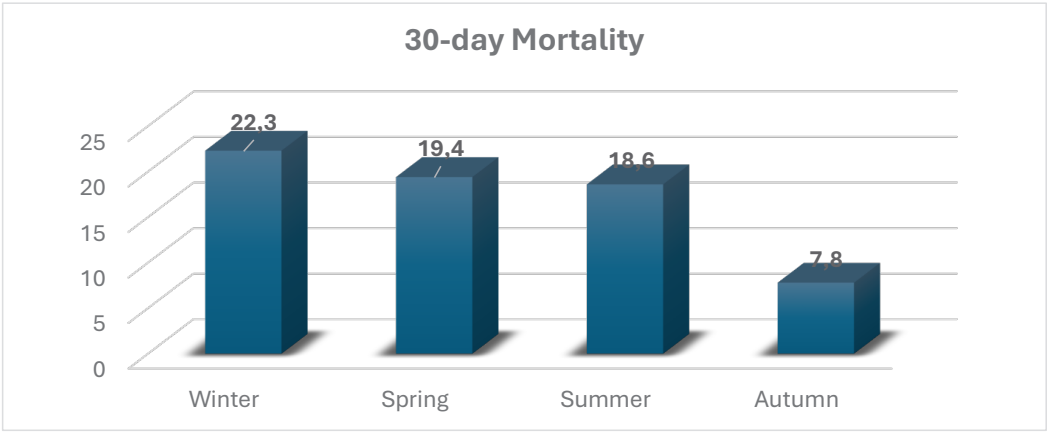

Figure 17. *30-day mortality rates across the year 2024*

also gives the first data for planning an effective FLS system, individualised in the Greek patients' profile.

Conclusions

2024 was a significant year for the Greek Fragility Hip Fracture registry. The combined efforts of the whole team led to the establishment of the project, as it managed to stay functional for a second year. The results of the first year have been presented in many local, national and international congresses (Including the Annual Orthopaedic Congress of OTEMATH and HAOST, as well as the 2nd European FFN Meeting in Istanbul), winning the prize of the best presented abstract in the 2nd European FFN Meeting. The first year's analysis of the registry was published in September of 2024 in the Archives of Osteoporosis Journal.[4]

During 2024 the team of the Greek Fragility Hip fracture registry grew significantly, with the inclusion of the two new orthopaedic departments as well as the four others that are in the inclusion process. We are looking forward for 2025 with the view of expanding the Registry team and extracting significant information about the Greek patients, which will be used to enhance the quality of the health services they receive across the nation.

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Cite this paper as

Iliopoulos E, Tosounidis T, Moustafa RM, Charmpi A, Tilkidis F, Daskalakis I, Melissaridou D, Sentona M, Graikos G, Kyprianou A, Tatani I, Gkiatas I, Chalidis B, Papachristos I, Zidrou C, Savvidou O, Drosos G. Greek Fragility Hip Fracture Registry 2024 Annual Report. AOTH. 2025;76(1):3-10.

AOTH

Review

Hallux valgus: choosing the appropriate surgical technique

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Abstract

The frequency of Hallux Valgus deformity in the general population is quite high, thus many orthopaedic surgeons, not only foot and ankle specialists, perform forefoot reconstructive surgery in their daily practice. Highly sophisticated techniques require deep knowledge, experience and completion of the learning curve in order to avoid some of the poorer outcomes documented within the literature. Distal, diaphyseal, metadiaphyseal and proximal types of osteotomies have been described according to the extent of the deformity. Fusion techniques have been modified to offer more predictable results. Frontal derotational osteotomies have been devised to address the metatarsal pronation element of Hallux Valgus pathology. Percutaneous techniques have evolved and are considered a safe solution to a certain and strictly defined spectrum of indications. A table of scenarios on Hallux Valgus deformities and their corresponding surgical treatment is proposed for decision-making. The osteotomy type choice is considered multifactorial and is certainly based on surgeons' experience, training and knowledge of the exact pathology of the deformity.

Keywords

Hallux Valgus; minimally invasive surgery; PECA; MICA; META; PETA; metatarsus adductus; scarf osteotomy; metatarsal pronation

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Introduction

The global incidence of Hallux Valgus deformity in the general population is around 19% [1], thus, many orthopaedic surgeons, not only foot and ankle specialists, perform forefoot reconstructive surgery in their daily practice.

It is widely accepted that the spectrum of Hallux Valgus deformities is complex and that a single operation is not suitable for the whole range of indications. Highly sophisticated techniques, such as the versatile open Scarf osteotomy or the 4th generation minimal invasive surgery (MIS) transverse osteotomy, require deep knowledge, experience and completion of the learning curve in order to avoid some of the poorer outcomes documented within the literature (Fig. 1) [2]. Consequently, one has to proceed with extreme caution regarding the type of deformity, along with the appropriate surgical technique selection.

In 1981, Helal counted more than 150 osteotomies to treat Hallux Valgus pathology, underlying the need for multiple osteotomy types to deal with this non-homogenous group of deformities [3]. Few of them are still in use, some have been added, such as the MIS techniques, and others have been devised to address the rotational deformities of the first ray. On the other hand, many of them have been abandoned throughout the years due to their high complication rates such as the original Wilson osteotomy because of the first metatarsal (MT1) excessive shortening and subsequent transfer metatarsalgia [4].

An orthopaedic surgeon has to keep in mind that cosmetically appearing post-operative scars, along with small incisions, are important for satisfaction-based scoring [5]. However, a red line between cosmetic perception and Cinderella surgery, also known as foot-narrowing surgery, should be drawn. Forefoot reconstructive procedures aiming to alter the size and shape of the feet of women in order to fit inside fashion high-heeled shoes should be considered with skepticism, as various and important medicolegal issues can be raised [6].

Hallux valgus spectrum

Hallux Valgus is a combined multiplanar deformity including valgus deviations of the great toe, known as hallux valgus, varus deviation of the first metatarsal bone, known as metatarsus primus varus and frontal rotational deformities, such as hallux and first metatarsal pronation or supination. The corrective osteotomies should address bony malpositioning in all three planes, transverse, frontal and sagittal, in order to rebalance the sesamoids just beneath the metatarsal head on plain post-operative radiographs and provide a functional and normal-appearing foot.

The development of Hallux Valgus is strongly related to other underlying pathologies or deformities. The rheumatoid population or individuals suffering from neuromuscular conditions, such as Parkinson's disease or cerebral palsy, are generally affected. Cases of metatarsus adductus, pes planus, juvenile Hallux Valgus onset, second toe amputation, first metatarsophalangeal joint (MTP1) arthritis, or general ligamentous laxity leading to first tarsometatarsal (TMT1) joint instability, may require specific forefoot reconstructive strategies.

Roger Mann in the early 1990s described a treatment algorithm based on the size of intermetatarsal angle (IMA) measurement on transverse plane [7]. Mild Hallux Valgus (IMA<13°), moderate Hallux Valgus (IMA: 13-15°), "gray zone" severe Hallux Valgus (IMA: 16-20°), severe Hallux Valgus (IMA>20°) and lateral deviation of the articular surface of the MT1 head, called distal metatarsal articular angle (DMAA), with or without loss of joint congruence, are basic parameters that are measured. After this assessment, the indicative reconstructive technique, osteotomy or fusion, in combination with distal soft tissue procedures is chosen.

Mild (IMA<13°) and incongruent MTP1 joint (DMMA<10°) deformities are simple cases a beginner surgeon should start with, in order to build his learning curve in forefoot surgery (Table 1). An open distal Chevron osteotomy should provide a sufficient corection. However, due to its short plantar orientation cut, high rates of avascular metatarsal head osteonecrosis have been reported. Helmy et al. [8] described a reversed 'L'-shaped distal first metatarsal osteotomy modification, which respects vascularity and preserves the plantar nutrient artery as an alternative to the original Chevron tech-

nique, resulting in fewer complications.

For moderate (IMA: 13-15°) and incongruent MTP1 joint (DMMA<10°) deformities performing a distal osteotomy is not considered the ideal option, due to the lack of geometry and limited lateral translation range of the distal first metatarsal fragment. These cases are preferably treated with a metadiaphyseal osteotomy, such as the scarf osteotomy, rather than a Chevron osteotomy.

Scarf osteotomy

Scarf osteotomy was popularized by L.S. Weil & S. Barouk [9] in 1992. It's an effective, versatile and reliable procedure, providing strong fixation and allowing early functional recovery.

The corrective scarf z-step osteotomy is not a diaphyseal osteotomy per se, but a metadiaphyseal one. The width of the longitudinal cut extends into the metaphyseal area of the metatarsal bone, both proximally and distally, thus preventing complications associated with troughing, such as limited lateral translation, pronation and elevation of the metatarsal head. "Gray zone" severe deformities (IMA: 16-20°) are suitable for the scarf technique, allowing enough lateral translation of the distal metatarsal fragment. The key point is to perform the transverse cuts perpendicular to the longitudinal axis of the second metatarsal shaft [10]. In that manner, the IMA is corrected and restored to normal, resulting neither in lengthening nor in shortening translation of the first metatarsal bone (Fig. 2).

The advantage of the scarf osteotomy is that it allows combinations of displacements [10]. Axial rotation of the plantar metatarsal fragment in the transverse plane leads to correction of the DMAA without the need for a second separate wedge osteotomy (Fig. 3). Consequently, the scarf osteotomy is considered more advantageous comparatively to the biplanar Chevron osteotomy when dealing with increased DMAA. Biplanar Chevron osteotomy results in first metatarsal shortening and transfer metatarsalgia due to wedge bone excision [11].

DMMA correction

Hallux Valgus deformity with a congruent MTP1 joint (DMMA>10°) is more often observed in juveniles, young adults and men [12]. However, the initial suspicion of an increased DMAA as measured in plain radiographs during the pre-operative planning process, is always confirmed during surgery (Fig. 4) and one should not be contented based on plain radiographs solely.

Failure to address and correct an increased DMAA after a first metatarsal osteotomy will result in an incongruent MTP1 joint, thus predisposing to deformity recurrence, MTP1 joint arthritic changes and stiffness [13].

Severe hallux valgus deformity: osteotomy versus Fusion

In severe Hallux Valgus deformities (IMA>20°) a debate between choosing a proximal, diaphyseal, metadiaphyseal osteotomy, TMT1 or MTP1 joint fusion exists in the academic foot and ankle community. Data derived from the USA[14], Switzerland[15], and Germany[16] reveal an equal tendency of approximately 50% towards fusion and osteotomy.

Proximal first metatarsal osteotomies, such as the proximal Chevron, crescentic and medial opening wedge osteotomy, provide great lateral translation of the distal metatarsal fragment in order to restore the IMA to its normal values. They seem to be an ideal solution when treating those large IMAs. However, they tend to be inherently unstable, especially in the sagittal plane, resulting in dorsiflexion malunion, delayed union and loss of correction [17].

The modified Ludloff diaphyseal osteotomy is considered an alternative to the scarf osteotomy, especially in cases of IMA>25° and a narrow first metatarsal, where scarf seems inadequate. The Ludloff procedure, as modified by Stamatis et al. [18], with the supplementation of a small locking plate acting as a medial buttress, prevents medial metatarsal drifting, providing extra stability to the osteotomy site.

On the other hand, severe IMA, especially in the older population, does quite well with MTP1 joint fusion with satisfying functional results [19]. The question that arises, is whether a single MTP1 joint fusion is adequate to restore the IMA to its normal

Table 1. Primary Hallux Valgus simple scenarios and their corresponding MT1 surgical treatment proposal.	
Clinical scenario	Surgical treatment
Mild IMA(<13°) and incongruent MTP1 joint (DMMA<10°)	Distal Chevron osteotomy or MIS transverse osteotomy
Moderate IMA(13-15°) and incongruent MTP1 joint (DMMA<10°)	Scarf osteotomy or MIS transverse osteotomy
"Gray zone" severe deformities (IMA: 16-20°) and incongruent MTP1 joint (DMMA<10°)	Scarf osteotomy or MIS transverse osteotomy
Moderate IMA(13-15°) and congruent MTP1 joint (DMMA>10°)	Scarf osteotomy enhancing DMAA correction
"Gray zone" severe IMA(16-20°) and congruent MTP1 joint (DMMA>10°)	Scarf osteotomy enhancing DMAA correction

Table 2. Primary Hallux Valgus advanced scenarios and their corresponding MT1 surgical treatment proposal.	
Clinical scenario	Surgical treatment
Severe IMA(>20°) in the older population	MTP1 joint fusion (without additional proximal MT1 osseous procedures)
Rheumatoid arthritis	MTP1 joint fusion (without additional proximal MT1 osseous procedures)
Moderate IMA and MT1 pronation	MIS transverse osteotomy
Severe IMA and MT1 pronation	Lapidus fusion
Mild to moderate metatarsus adductus (Sgarlato angle:21-30°)	MTP1 joint fusion
Severe metatarsus adductus (Sgarlato angle>30°)	Consult expert's opinion (TMT1 + TMT2 + TMT3 joint fusion)
Severe IMA(>20°) in the adult population with widened MT1	Scarf osteotomy or modified Ludloff osteotomy
Severe IMA(>20°) in the adult population with narrow MT1	Modified Ludloff osteotomy
TMT1 joint arthritis with any degree of IMA severity	Lapidus fusion
Primary TMT1 joint instability due to generalized ligamentous laxity	Lapidus fusion
Severe IMA(>20°) with increased DMAA(>10°)	Lapidus fusion and a distal first metatarsal derotational osteotomy (e.g. Reverdin osteotomy)

values. Ripstein [20] showed that the combination of a more proximal surgical correction and an MTP1 joint fusion was beneficial in those severe cases. However, the necessity this type of proximal supplementation was not proven by Ripstein's study. Many authors have underlined the fact that after performing a proper MTP1 joint fusion, no additional proximal procedures are required (Fig. 5). The adduction shifting of the first metatarsal is restricted because the flexor, extensor, and adductor tendons are converted from deforming forces to corrective forces [21].

TMT1 joint fusion (Lapidus procedure) is an available solution when treating severe IMA Hallux

Figure 1: *(A) Radiography presenting hallux valgus deformity correction in a female rheumatoid patient after bunionectomy and distal soft tissue procedures alone, without MTP1 joint fusion. (B) Corresponding clinical photo.*

Figure 2: *Intraoperative fluoroscopic image during Scarf osteotomy. Note that the orientation of the guide pins for the distal and proximal transverse cuts is perpendicular to the longitudinal second metatarsal axis and not perpendicular to the longitudinal first metatarsal axis. In that manner, lengthening or shortening of the first metatarsal bone can be avoided.*

Valgus deformities. Although it's the most powerful corrective surgical treatment, high complication rates can occur, such as MTP1 joint nonunion, first metatarsal shortening, IMA overcorrection and deformity recurrence [22]. Indications for Lapidus fusion are generalized ligamentous laxity, metatarsus adductus deformity, TMT1 joint arthritis (Fig. 6) and severe IMA with increased DMAA, without TMT1 joint arthritis [23]. In this case, where the scarf osteotomy is inadequate to fix both IMA and DMAA, a distal first metatarsal derotational osteotomy combined with TMT1 joint fusion can provide satisfactory results. A Lapidus arthrodesis is the indicated procedure in rare cases of generalized ligamentous hyperlaxity where the TMT1 joint is primarily affected and unstable.

The concept of primary TMT1 joint instability has been over-projected through literature in the past. During the 1990s, many papers emphasized the role of TMT1 joint laxity as a prime pathoetiology factor in the onset of Hallux Valgus, and as a result, the Lapidus procedure was popularized [24]. However, recent literature [25] has proven that after IMA reduction with a metatarsal osteotomy, TMT1 joint hypermobility is reduced to normal. The modern hypothesis is that TMT1 joint laxity is secondary due to the pushing effect of the proximal phalanx onto the head of the varus deviated first metatarsal. TMT1 joint stability is affected by first ray alignment and is not an intrinsic characteristic of the joint [26].

Metatarsal pronation

During the last ten years, frontal plane rotational deformities have been given the required attention and importance, and thus Hallux Valgus pathology is considered a three-dimensional deformity. Based on computed tomography (CT) scan measurements, the incidence of first metatarsal pronation is approximately 87% in the Hallux Valgus population [27] and it doesn't seem easy to assess in plain radiographs pre-operatively. A round-shaped metatarsal head on post-operative radiographs (positive round sign) [28] represents a metatarsal pronation deformity that has not been addressed. Failure to correct this kind of rotational deformity may lead to unbalanced

Figure 3: *(A) Radiographic pre-operative planning – congruent MTP1 joint with increased DMMA:18° in a male adult patient. (B) Post-operative radiography showing the axial rotation of the plantar metatarsal fragment in the transverse plane during Scarf osteotomy in order to achieve normal values of DMAA and subsequently a congruent MTP1 joint after reduction.*

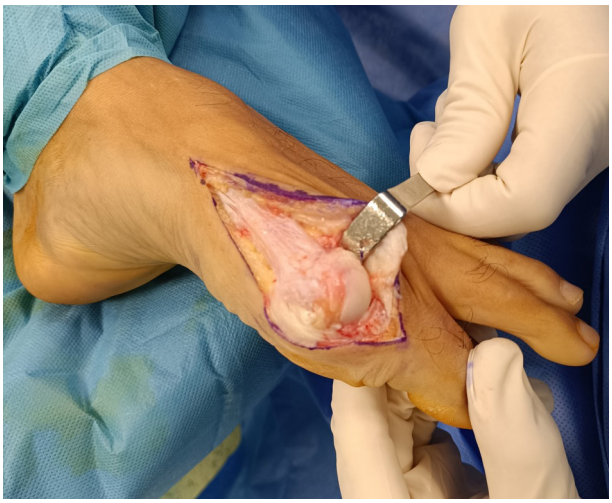

Figure 4: *Peri-operative exposure and direct visualization of the first metatarsal head offers exact confirmation of MTP1 joint congruency.*

sesamoid grading and Hallux Valgus recurrence. Sesamoid correction strongly relates to metatarsal pronation [29].

The versatile scarf osteotomy is capable of derotating the first metatarsal and correcting metatarsal pronation by removing a bone wedge from the plantar metatarsal fragment [30]. However, this modification is technically demanding and might be difficult for inexperienced hands.

The Lapidus arthrodesis, the proximal oblique sliding closing wedge osteotomy (POSCOW) [31] and the proximal supination osteotomy supplemented with an X-shaped locking plate as described by Okuda et al. [32] have the potential to correct metatarsal pronation, however, they lack stability, apart from the Lapidus procedure.

Wagner et al. recently presented the Proximal Rotational Metatarsal Osteotomy (PROMO) [33] providing encouraging short-term results. Extended, long follow-up studies are mandatory in order to draw safe conclusions.

Metatarsus adductus

Metatarsus adductus is a complex midfoot and forefoot deformity whose onset is in utero. The main characteristic is a large Hallux Valgus Angle combined with mild to moderate IMA. The whole forefoot is adducted at the level of tarsometatarsal joints, and all metatarsal bones, both the first and lesser ones, are medially deviated. Those feet are quite difficult to treat, requiring experienced surgeons. One should seek expert's consultation regarding surgical strategy in these demanding cases. However, identifying this complex deformity on plain weight-bearing radiographs is essential. Calculating the modified Sgarlato angle, a composite measurement between the angulation of midtarsal bones and the longitudinal axis of the second metatarsal bone, is of paramount importance [34]. Values between 10° – 21° are normal, whereas cases with a Sgarlato angle between 21° – 30° are considered mild to moderate and values >30° are severe. No consensus regarding surgical treatment exists. Correcting only the Hallux Valgus deformity in mild metatarsus adductus cases by using a first metatarsal osteotomy will lead to a recurrence rate of between 30%

Figure 5: *(A) Radiography presenting severe hallux valgus deformity (IMA:26°). (B) Post-operative radiography presenting proper MTP1 joint fusion without additional proximal osseous procedures.*

and 80%, thus, this surgical strategy, is not considered the best option[35]. Severe metatarsus adductus can be treated with first, second and third TMT joint fusion in order to realign the hindfoot, midfoot and forefoot (Table 2). In some mild adductus cases, the surgeon can proceed with MTP1 joint fusion in combination with distal Weil or Fowler lesser metatarsal head osteotomies in an effort to realign the forefoot. A combination of reconstruction procedures has also been published using MIS techniques[36].

Minimally invasive surgery (MIS)

In the early 2010s, the Educational Committee of EFAS[37] welcomed and applauded MIS forefoot reconstructive techniques as an innovation for improved, safer, and maybe cheaper treatment for patients. However, they expressed criticism and concern about that trend and emphasized the necessity for prospective and randomized trials with long-term results to provide sufficient data regarding the superiority and safety of those techniques. In addition, they projected their worries regarding the over-promotion of industry-guided educational MIS courses before such studies had been conducted.

In 2016, Vernois et al.[38] and Lam et al.[39] introduced their 3rd MIS generation technique, since the first and

Figure 6: *(A) Radiography presenting hallux valgus deformity with TMT1 joint arthropathy. (B) Post-operative radiography presents an inadequate surgical strategy as it does not address the TMT1 joint arthropathy. Such combined Hallux Valgus cases should be preferably treated with Lapidus fusion. (C) Another clinical example. Radiography presenting hallux valgus deformity with concomitant TMT1 joint arthropathy. (D) Post-operative radiography presents the correct surgical approach with Lapidus fusion.*

second generations had been abandoned through literature because of published disappointing results and catastrophic complications[40]. The 3rd generation Minimally Invasive Chevron and Akin (MICA) os-

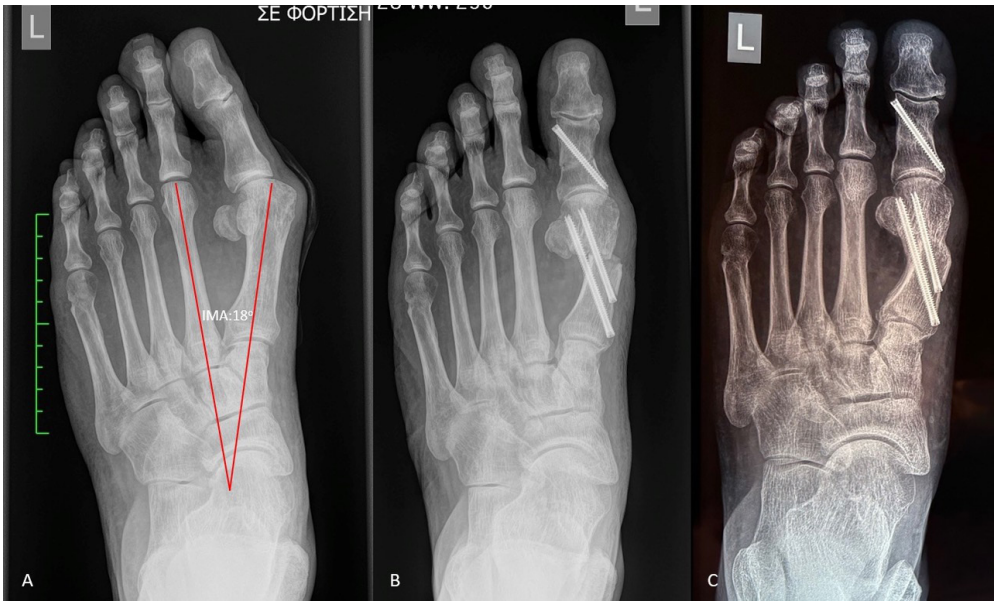

Figure 7: *(A) Radiography presenting "gray zone" severe Hallux Valgus (IMA: 18°) hallux valgus deformity. (B) Post-operative radiography presenting 4th generation MIS distal transverse extra-capsular osteotomy fixed with two non-beveled screws. (C) One year post-operative radiograph of the same foot. Note the secondary bone healing formation inside the displacement site.*

teotomy, named by Vernois, and the 3rd generation PErcutaneous Chevron/Akin (PECA) osteotomy, named by Lam respectively, gained popularity and clinical traction among surgeons in Europe and Australia in patients with mild to moderate Hallux Valgus deformity (IMA<20°) and in strictly selected patients with severe deformity (IMA>20°) [41,42,43,44]. Several level I prospective midterm follow-up publications have shown the adequacy of these methods regarding clinical and radiological outcomes compared to open osteotomies [45]. In addition, post-operative benefits, such as fewer wound complications, reduced swelling, better cosmetic scars and shorter rehabilitation time have also been underlined [46].

In 2020, there was a transition from a percutaneous distal MT1 Chevron osteotomy to a percutaneous distal MT1 transverse osteotomy [44]. This evolution to a 4th generation MIS technique was given several logos, such as Metaphyseal Extra-articular Transverse and Akin osteotomy (META) [47], or PErcutaneous Transverse Akin (PETA) [48], or the new PECA technique,[44] adopting beveled screw fixation. The reason for this osteotomy "switch" was the fact that a transverse cut could more easily address MT1 pronation deformity, providing better bicortical stability and an easier learning curve [49].

However, many questions arise regarding the healing process surrounding the MIS transverse osteotomy site, especially when viewing near 100% bony shift and no osteotomy contact on post-operative radiographs. Concerns about a possible nonunion or delayed union sound logical, on the other hand they have not been justified (Fig. 7). A recent study by Spacek et al. [50] underlines the fact that the 3-dimensional soft tissue pyramid-shaped space, which is created after the extra-capsular MIS osteotomy, between the medial border of the MT1, the osteotomy site, and the preserved periosteum, is vital for the secondary bone healing process through hematoma formation. The osseous healing is therefore maximized with the aid of rigid screw fixation, allowing full weight-bearing post-operatively by applying Wolff's law.

Although recent studies from highly experienced MIS surgeons and meta-analytic data show encouraging, equivalent, or even superior results of 4th generation MIS techniques compared to standard open surgery [51,52], other meta-analytic data do not fully confirm those conclusions [53]. More robust, high-qual-

ity, prospective clinical studies, with larger patient numbers, are paramount to obtain more validated data regarding 4th generation MIS techniques and allow further recommendations.

Conclusions

Choosing the indicated surgical technique to treat Hallux Valgus deformities is multifactorial. Applying a unique osteotomy that suits all Hallux Valgus spectrum is malpractice, and this is an undeniable truth. The choice is certainly based on surgeons' experience, training and knowledge of the exact pathology of the deformity. Aiming to shorten the learning curve, especially in MIS techniques, by undertaking multiple cadaveric courses is preferable. High-quality and validated evidence through literature is mandatory to draw gold-standard treatment strategies.

Conflict of Interest

The authors declared no conflicts of interest.

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Cite this paper as

Petrakis I, Hatziemmanuil D, Evaggelou E, Simeonidis P, Badekas A, Psychogios V. Hallux valgus: choosing the appropriate surgical technique. AOTH. 2025;76(1):11-21.

AOTH

Review

The effect of hip arthroplasty on gait. A review

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Abstract

Hip arthroplasty is one of the most successful orthopaedic procedures because it offers pain relief and good postoperative function. However, some patients complain of gait changes and a marked reduction in their walking pace. These changes may be due to altered offset, leg length discrepancy and hardware positioning and may persist even a year after their operation . This review aims to assess hip replacement-related gait alterations as well as their causes and their clinical impact. Gait analysis after THR can provide important information that could improve our decision making in our clinical practice.

Keywords

Hip replacement; gait changes; leg length discrepancy; global offset; femoral stem anteversion

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Introduction

Total hip replacement (THR) is considered one of the most successful orthopaedic procedures. This is because it offers a satisfactory surgical outcome along with considerable pain alleviation. The majority of patients who elect to undergo THR present end-stage osteoarthritis (OA). The latter experience significant loss of their functionality and are incapable of walking and performing their daily activities. Moreover, they often complain of gait changes and a marked reduction in their walking pace.

Regardless, 10–20 % of THR patients continue having issues regarding their working capacity, gait pattern, overall function and quality of life postoperatively.[1,2] Despite being relatively rare, gait asymmetry and noticeable limping may persist.[3,4] With pain and impaired function being the main indications for surgery, THR is considered unsuccessful in such cases. This review aims to assess THR-related gait alterations as well as their causes and their clinical impact.

Gait analysis

The variables investigated in gait analysis are spatiotemporal, kinematic and kinetic (Figure 1). Spatiotemporal parameters are distance-related. They include step and stride length as well as time-related parameters such as walking speed and stride time. Kinematic gait variables investigate the angular motion of the body, limbs, and joints during movement. Kinetic gait variables explore the forces resulting from movement.

Most studies investigating gait changes after THR compared their results with those of healthy subjects. Reduced walking speeds, step and stride lengths and gait deviation are commonly identified. Furthermore, coronal and sagittal range of motion deficits have also been reported.[5,6] In addition to these findings, several studies refer to poor trunk control in the mediolateral direction.[7,8] The former could be attributed to a posture consisting of lateral bending toward the affected side. The reduction in the volume of gluteus minimus has been identified as a factor involved in this gait deviation and contributes to higher hip joint loads up to 3 months after the intervention.[9] Likewise, the atrophy of this muscle has been used as a predictor of the weakness of the gluteus medius, which is the dominant hip abductor.[10] As a result, the mechanical demand on weaker hip abductor muscles is reduced further while the balance in the frontal plane is facilitated. However, the load asymmetry between the two limbs increases the number of stresses put on the contralateral hip joint and could potentially lead to OA, or increase the risk of falls.

Bahl et al. assessed changes in gait biomechanics after THR. They compared the postoperative status of THR patients to healthy controls up to 2 years after surgery. This systematic review illustrated moderate to large pre to post-operative changes from 6 weeks to 12 months in spatiotemporal and kinematic parameters. Functional and clinical improvements were apparent as early as the sixth postoperative week. Nevertheless, greater improvements were documented in 6 months, with the best results appearing approximately one year after the surgery. Although some parameters turned near normal after THR, residual deficits in walking speed, stride length and sagittal plane hip ROM existed at 12 months postoperatively. Step width was wider compared to healthy individuals at 6 weeks and 3 months. The kinematic data revealed increases in sagittal and transverse plane hip ROM at 6 weeks and up to 12 months whilst coronal plane hip abduction/adduction revealed no significant change.[11]

Naili et al. indicated improvement in performance-based and patient-reported functions a year following THR, even though greater improvement was documented in patient-reported functions. These findings suggest that objectively measured improvements in performance-based function and gait are not in line with patient-reported functional improvements. Therefore, they highlighted the importance of using both subjective and objective methods for evaluating function following THR.[12]

Kaufmann et al. investigated the functional outcome of THR. Apart from comparing OA patients with normal controls they also documented the pre and postoperative outcomes in OA patients. They indicated that walking speed and cadence improved significantly in postoperative assessments of patients with hip OA. Stride duration decreased

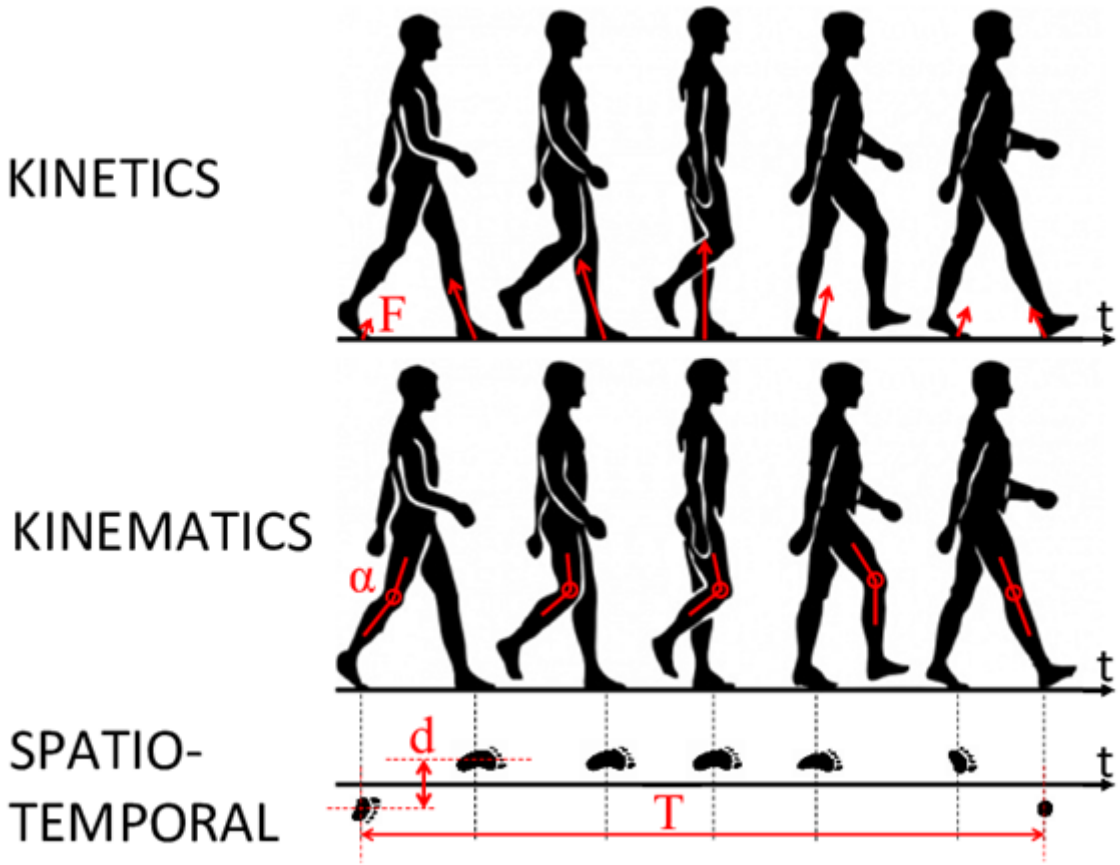

Figure 1. *Kinetic gait variables explore the forces resulting from movement. Kinematic gait variables investigate the angular motion of the body, limbs, and joints during movement. Spatiotemporal parameters are distance-related. They include step and stride length as well as time-related parameters such as walking speed and stride time.*

after surgery whilst there was no significant difference in stride length postoperatively. Moreover, hip flexion angles during stance and swing and knee flexion angles during loading response and swing were significantly larger postoperatively. Conversely, knee flexion angles during terminal stance were significantly smaller postoperatively whereas THR had no impact on ankle kinematics. When compared to healthy controls, kinematic parameters improved and did not differ from asymptomatic controls 1 year postoperatively. In contrast, spatiotemporal parameters improved postoperatively but remained inferior to asymptomatic controls.[13]

Foucher et al. suggested that the preoperative gait status may be related to the postoperative outcome.[14] The same primary author also demonstrated that preoperative gait, clinical factors and patient characteristics predicted up to 33% of the variability in postoperative gait.[15] They also proposed that intense preoperative and postoperative rehabilitation could be helpful for some THR patients.[14] , Indeed, some studies confirmed improvements in post-operative walking speed and stride length after a peri-operative exercise programme, in comparison with conventional care regimens.[16]

To achieve personalization of the prosthesis and optimal therapeutic effect after THR, surgeons put great effort into selecting the best combination of implant components. Choosing adequate implants and meticulous hardware positioning during total hip replacement is important for improving the outcome and maximizing the results of the surgery. Following a carefully tailored surgical plan may also facilitate restoring limb function and hip biome-

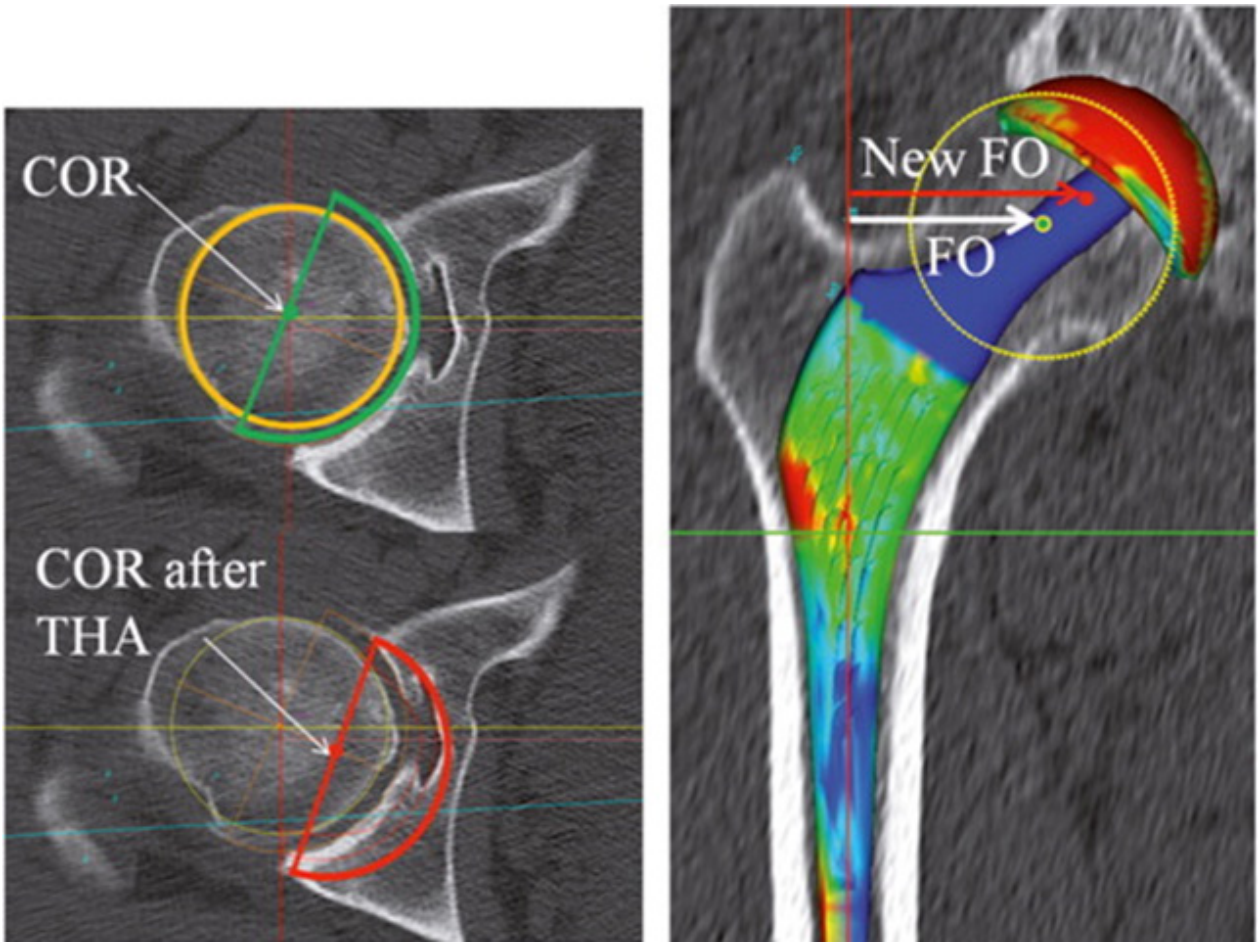

Figure 2. *Medialization during acetabular preparation reduces the GO. To restore the latter, a stem with a higher offset may be required. The compensatory increase of femoral offset (FO) is indicated because it reduces the risk of dislocation, decreases polyethylene wear, lowers the risk of edge loading and restores soft tissue tension.*

chanics, rehabilitation and help lower socioeconomic factors associated with total joint replacement.

The number of studies investigating the effect of the implant head size on the gait pattern after total hip replacement is limited.[17] Large femoral head implants have been linked to a higher risk of taper corrosion and groin pain due to impingement of the head implant on the psoas muscle. Since the femoral head size has a proven impact on the range of motion, it is highly probable that it also alters the gait pattern or at least some parameters of gait that may be important in the rehabilitation process. Stolarczyk et al. studied gait parameters in THR patients depending on the size of the femoral head implant. They concluded that 36mm femoral heads offered better results in terms of gait pattern, with values that were not significantly different from healthy hips. However, a drop of the contralateral side of the pelvis during support was more common in the group where large head size was preferred than in healthy hips, both in the operated limb and healthy limb.[18]

Offset

Restoring the global hip offset (GO) in THR is incremental for maintaining optimal hip function. Medialization of the cup is not uncommon in THR, especially in cases where medial osteophytes are present. However, medialization during acetabular preparation reduces the GO. To restore the latter, a stem with a higher offset may be required (Figure 2). The compensatory increase of femoral off-

Table. Summary of the most important published related studies on gait changes in THR.

Study	Purpose	Results
Bahl et al. [11]	Changes in gait biomechanics after THR	Improvements were concluded from 6 months, with the best results appearing approximately one year after the surgery.
Naili et al. [12]	improvement in performance-based and patient-reported functions a year following THR	Objectively measured improvements in performance-based function and gait are not in line with patient-reported functional improvements
Stolarczyk et al. [18]	Gait parameters in THR patients depending on the size of the femoral head implant	36mm femoral heads offered better results in terms of gait pattern, with values that were not significantly different from healthy hips
Sato et al. [23]	The effect of GO and leg length discrepancy (LLD) on hip joint muscle strength and gait trajectory	Global FO reduction by > 5 mm after THR was associated with hip abductor muscle weakness
Tokuhara et al. [27]	Anterior knee pain after THR	Associated with increased lateral patellar tilt and leg lengthening
Renkawitz et al. [30]	The effect of LLD and offset changes after THR	Residual LLD and an FO difference greater than 10 mm led to low patient-related outcome scores and changes in gait symmetry

set (FO) is indicated because it reduces the risk of dislocation, decreases polyethylene wear, lowers the risk of edge loading and restores soft tissue tension. Moreover, restoring FO has a positive effect on isometric hip abductor strength[19], walking speed, and knee flexion and extension 1 year after THR.[20] Restored FO has also been shown to influence knee joint moments but has no apparent impact on hip joint moments.[21] Most studies have focused on the FO in relation to gait and function. However, both the FO and acetabular offset (AO) are important to consider when restoring hip joint anatomy.

Chamnongkich et al[22] suggested that a moderately increased FO may be effective for enhancing hip abductor muscle function and ambulatory balance after THR. Regardless, the abductor isometric strength was found 9% and 25 % lower in high FO and lower FO patients respectively, compared to the non operated limb. These results are in line with Sariali et al. who reported that the ROM required for activities of daily living decreased by more than 20% in patients with a 15% postoperative reduction of their offset.[20]

Further investigating the impact of offset on the postoperative gait of THR patients, Sato et al investigated the effect of GO and leg length discrepancy (LLD) on hip joint muscle strength and gait trajectory. His results showed that reduction of global FO by > 5 mm after THR, compared to the contralateral hip, was associated with hip abductor muscle weakness. He postulated that straight leg raise (SLR) strength is important for generating sufficient forward thrust when walking and that it influences the stride length and strength of the lower limb forward swing. Therefore, SLR weakness would lead to asymmetry of gait trajectory in the sagittal plane.[23]

Implant orientation

Implant orientation is crucial in THR. Despite the femoral stem anteversion (FA), the anteversion of the cup must also be taken into consideration, since

the combined anteversion is of importance when considering the risk of hip impingement and dislocation. The proposed safe zone differs greatly in the literature depending on the varying geometrical definitions of the measurements as well as on the surgical approach and prosthetic types. The acetabular cup is usually implanted following the 45-degrees abduction - 15-degrees anteversion rule, whilst others use the transverse acetabular ligament as a guide for anteversion. Furthermore, when the surgeon elects a cementless type of fixation, anteverting the femoral stem according to the preoperative plan may not be feasible. Anteversion of cementless femoral stems may be restricted by the endosteal anatomy of the femoral neck, the diaphyseal bow, and the anterior-posterior isthmus at the level of the calcar femorale.[24] In addition, there has been a great debate about which is the most accurate way to evaluate intraoperatively femoral anteversion. Various reference points like the posterior condylar and transepicondylar lines, the calcar and the linea aspera have been proposed. In a study performed by Lee et al, it was supported that the femorotibial angle influenced the discrepancy between intraoperative estimation and the real FA. When the former was decreased such as in a varus knee, the intraoperative measurement underestimated the FA.[25]

Despite the abundance of articles investigating the effect of FA on hip postoperative stability, the impact of FA changes on a individual's gait pattern is not described extensively. In a recent study, Esbjörnsson et al. used computed tomography and three dimensional gait analysis to investigate whether geometrical restoration in THR leads to gait pattern alterations. They supported that changes in hip rotation during walking were associated with changes in FA in the same direction as well as changes in pelvic rotation in the opposite direction during gait.[26] Changes in rotation after THR may affect gait, daily activities, the rate of dislocation of the hip, and ipsilateral knee pain. The latter is an independent factor leading to gait alterations.[26]

According to Tokuhara et al. anterior knee pain after THR is associated with increased lateral patellar tilt and leg lengthening.[27] Furthermore, increased internal rotation of the hip may influence the axial alignment of the ipsilateral knee. There are various factors leading to increased femoral rotation. These can be associated with underlying disease (OA), less pre-operative internal rotation, female gender, posterior surgical approach, leg lengthening, and an increase in femoral anteversion.[28]

Leg length discrepancy

The occurrence of LLD is another factor leading to postoperative gait changes after THR. Marked LLD after THR is a major cause of patient dissatisfaction due to abnormal gait mechanics that lead to knee and back pain, early prosthesis loosening, and revision surgery. Beard et al. reported that patients with a LLD > 10 mm had significantly worse Oxford hip scores three years after surgery.[29] In addition, Renkawitz et al. reported that residual LLD and an FO difference greater than 10 mm led to low patient-related outcome scores and changes in gait symmetry.[30] In cases where postoperative LLD exceeds 20mm, walking speed and stride length are significantly reduced.[31] However, other researchers supported that the kinematic symmetry and loading on the hips during level walking and stair ascending were not markedly affected even when postoperative LLD was up to 20 mm. Therefore, according to them, the use of insoles in such cases was not biomechanically justified.[32]

Nevertheless, it is beyond dispute that when the leg is lengthened the tensor fasciae lata, iliotibial band, and quadriceps cross the hip and knee joint and become stretched. When the iliotibial band is stretched the patellofemoral kinematics are altered.[33] Consequently, tension is put on the lateral retinaculum thus causing increased lateral patellar tilt. Furthermore, due to changes in posture, valgus deformities may occur.[34] Especially in cases of developmental dysplasia of the hip, where leg lengthening and medialization of the hip center are combined, consequent medialization of the hip may lead to medialization of the knee. In such cases, the patient would either try to walk with a wider interfoot distance to avoid striking the contralateral side or attempt to bring the knees closer together and keep the joint line horizontal. Both of these pos-

tures may predispose the knee to valgus deformity. The postoperative mLDFA is a major factor related to knee valgus alignment after THR, which combines the preoperative anatomy and surgical reconstruction.[35] A high-offset femoral component is indicated to compensate for the medialization of the hip center.

Conclusion

Review of the related literature for the purpose of this study (Table) showed that abnormal gait patterns may persist up to 1 year after THR. Identifying gait changes after THR can offer important information about the manner the hip joint works and its impact on adjacent joints. The identification of abnormal walking patterns will help us understand their causes and will eventually make us learn how to make better decisions in our clinical practice.

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Cite this paper as

Economopoulos DG, Lilikakis AK, Poultsides LA, Nikolaou VS. The effect of hip arthroplasty on gait. A review. AOTH. 2025;76(1):23-31.

AOTH

Review

Peri-tendinous injections. An overview of agents and their efficacy

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Abstract

Tendinopathy is the clinical entity representing chronic tendon injury, and it is relatively common, affecting about one-fourth of adults during their lifetime. Non-invasive management of tendon disorders includes various peri-tendinous injections. Ultrasound-guided peri-tendinous injections is a non-invasive technique with potentially therapeutic effect for tendinopathy. Commonly used drugs and agents include topical corticosteroids, PRP, autologous whole blood, hyaluronic acid, hyperosmolar dextrose, and needle tenotomy. The routine use of NSAIDs and peri-tendinous corticosteroid injections are being re-evaluated since histologic examination of pathologic tendinous tissue has shown no signs of inflammation. New non-invasive tools such as PRP, autologous whole blood, and hyaluronic acid are being investigated. These agents have been proven effective in alleviating pain and histologically improving tendon injuries. Prolotherapy is a rapidly spreading approach, but its effectiveness is currently vastly studied compared to other interventions. The simple needle fenestration of the injured tendon has also shown promising results and can be used alone or in combination with tested drugs and agents. The literature lacks extensive high-quality double-blinded clinical trials that will test the efficacy of different peri-tendinous injections and conclude which method leads to the best results. This mini-review aims to discuss the above options as far as their indications and their use are concerned.

Keywords

Tendinopathy; PRP; hyaluronic acid; prolotherapy

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Introduction

Tendons are fibroelastic structures of tenocytes and tenoblasts in a rich extracellular matrix network. Tendon injuries are widespread and can be either acute or chronic [1]. Acute injuries usually include partial or complete ruptures due to extrinsic forces exceeding the tendon's resistance capacity. A combination of extrinsic and intrinsic factors causes chronic injuries. Repetitive overloading of tendons can cause trauma or accumulative microtrauma, leading to a pathological healing response [2]. Histologically, healing seems impaired, with collagen fibre disorientation and thinning, hypercellularity, absence of inflammatory cells, neovascularity, and increased glycosaminoglycan deposition [3].

Tendinopathy is a clinical entity representing chronic tendon injury. This is relatively common, affecting about one-fourth of adults during their lifetime [4]. Athletes' increasing performance demands and the wide spread of sports as hobbies in more mature age groups have augmented the risk of primary tendon lesions over the last decades [5]. The tendons most usually affected are Achilles, patella, rotator cuff tendons, wrist extensors and flexors, posterior tibial, and biceps femoris [6], but every tendon can be affected.

Treatment options are abundant for tendon disorders. However, there is no consensus on tendinopathy management[7]; treatment choice usually depends on empirical observations. Physical therapy, rest, training modification, NSAIDs and various peri-tendinous injections are a few of the available preservative options, but the results are almost always temporary and inconsistent. Surgical treatment should be preserved for cases that do not improve with less invasive approaches [8].

Peri-tendinous injections: agents and techniques

Ultrasound-guided intra and peri-tendinous injections is a non-invasive technique with potentially therapeutic effect for tendinopathy, and it is being extensively investigated [9] in contemporary literature. Many different agents and drugs are being tested in experimental and cohort studies, with the effectiveness results awaiting proof. The authors conducted a thorough literature overview to introduce the most usual drugs used in peri-tendinous injection and their potential effectiveness.

Corticosteroid injections

Peri-tendinous corticosteroid injections are the most popular and widely used [10] in chronic tendinopathies, despite the sheer lack of benefit presented in current literature [11].

Local steroids are used to decrease pain via topical inflammatory process restriction. Histologically, tendinopathy does not include signs of inflammation but is merely a pathologic healing reaction. In the rare situation with an inflammatory response, it is an indispensable part of the healing course against injury or continuous microtrauma, and its disruption can lead to adverse effects. Steroids can harm tendons' biomechanics, degrading collagen, decreasing fibroblast proliferation, and increasing inflammation and cytotoxicity [12].

The biochemical effects of steroids on tendon structures have been proven harmful in animal models [13, 14], but evidence has not yet been established in human tendons. However, there have been case reports of tendon rupture after peri-tendinous steroid administration [15, 16] and studies showing a positive correlation between local steroid usage and tendon tears [17].

Subsequently, peri-tendinous steroid injections can transiently alleviate pain and partially restore range of motion but seem to cause more damage than good at cell and tissue level, with possible long-term tendon atrophy, rupture and other adverse effects.

Platelet-Rich-Plasma injections (PRP)

PRP is autologous patient plasma with a higher concentration of platelets [18] (three to eight times higher than whole blood). Platelets are derived from megakaryocytes and, except for being essential to blood clot formation, they release many active biomolecules containing growth factors. Platelet-derived growth factor (PDGF), transforming growth factor-β (TGF-β) and vascular endothelial growth factor (VEGF) are the most important agents excreted by platelets, which actively assist in the healing process. According to the literature, platelets might

Table 1: Pros and cons of the different types of peri- tendinous injections

Type of peri-tendinous injection	**Pros**	**Cons**
- Corticosteroid injections	- Pain relief - Inflammation reduction	- Cell and tissue damage - Tendon atrophy - rupture
- PRP injections	- Pain relief - May offer definite treatment	- Effectiveness still under investigation
- Hyaluronic acid	- Enhancing collagen production - Enhancing proliferation of mesenchymal cells - Accelerate tendon recovery	- Unknown mechanism of action - Not effective on inflammation
- Whole blood	- Low cost - Ease of use and preparation	- Little literature comparing its effectiveness
- Dextrose prolotherapy	- Pain relief - Amelioration of ROM	- Variable results
- Percutaneous tendon fenestration	- Reactivates healing process - Microtrauma liberates growth factors	- Usually, needs to be combined with other injection therapy, like PRP

even promote stem cell recruitment and collagen production from fibroblasts [19].

Peri-tendinous PRP injections have shown promising results in chronic tendinopathy management [20, 21, 22, 23, 24, 25]. Platelets are activated after they are injected into the tendon via their interaction with free collagen and release growth factors that promote and augment the healing course of actions. The generative effect of PRP has been proven histologically, and PRP injections have shown clinical improvement in pain and range of motion in cases with different kinds of tendinopathy. The rapidly increasing interest in PRP injections is unveiled in the numerous currently registered studies investigating its effectiveness.

The reactivation of the healing process seems connected to the resumption of an inflammatory state, and leukocytes play a tremendous role in inflammation. PRP can currently be divided into leukocyte-rich (LR-PRP) and leukocyte-poor (LP-PRP). The interaction between leukocytes and platelets can be pro or anti-inflammatory with regenerative potential. This combination of autologous cells may offer the definitive therapeutic effect that is pursued but is still being studied with promising future results [26].

Hyaluronic acid

Hyaluronic acid (HA) is a high–molecular-weight glycosaminoglycan and the primary component of synovial fluid, providing lubrication and shock absorption [27]. It is also one of the fundamental components of tendon tissue, contributing to its biomechanical properties. It has been tested in several clinical trials as a therapeutic means for managing tendinopathy. It has been proven effective in patients with rotator cuff tendinopathy [28, 29, 30], tennis elbow [31], patellar [32] and Achilles [33] tendinopathy.

Although the exact mechanism of action is not yet thoroughly investigated, peri-tendinous HA injections accelerate tendon recovery by enhancing collagen production and proliferation of specific mesenchymal cells, such as chondrocytes and hematopoietic cells [34]. The viscoelastic effects of HA on connective tissue have been suggested to warrant its use for tendinopathy management. Hyaluronic acid

has been proven to improve function and reduce pain without the complications of corticosteroids. Further research needs to be conducted to determine the stages of tendinopathy that can benefit the most from HA injections [35].

Whole blood

Compared to PRP, autologous whole blood injections present decreased cost and ease of preparation and use. In addition, clinical benefit has been shown concerning pain and mobility improvement. Thus, the effects of autologous whole blood versus PRP injections are worth investigating. According to the literature, whole blood is equally effective to PRP in managing lateral elbow tendinopathy [36] and hamstring tendinopathy [37]. However, certain reviews suggest the superiority of PRP for specific tendon disorders. Further investigation needs to be conducted to assess the cost-effectiveness of this debuting non-invasive approach meticulously.

Dextrose prolotherapy

Prolotherapy with hypertonic dextrose has been used for years for chronic musculoskeletal pain with variable results in literature [38]. Prolotherapy has also been introduced as a non-invasive treatment option in tendinopathy management.

The suggested mechanism of action includes the initiation of the inflammatory response cascade and enhancing the tendon healing process. Peri-tendinous hypertonic dextrose infusion can induce mesenchymal cell proliferation and collagen production [39], significantly improving range of motion (ROM) and pain.

Prolotherapy is a rapidly spreading means for preservative treatment of various soft tissue disorders. The literature lacks high-quality research assessing the effectiveness of hyperosmolar dextrose injections in chronic tendon disorders. Some reviews suggest little to no benefit from prolotherapy [40], whereas other studies have presented amelioration of mobility and pain in Achilles [41] and rotator cuff [42] tendinopathy. Further well-organized double-controlled trials are necessary to conclude the debate on prolotherapy effectiveness for chronic tendon disorders.

Percutaneous tendon fenestration or needle tenotomy (PNT)

Ultrasound-guided tendon fenestration has also been used successfully in managing chronic tendon disorders and even tendon tears. The technique includes passing a needle several times (20-25) through the tendinous tissue. The rationale behind this technique is converting a failing chronic healing process into an acute response [43] by multiple needle microtrauma. In addition, the induced bleeding provides the tendon with autologous red blood cells and platelets, which release healing-promoting growth factors.

The improvement of tendinopathy-related symptoms via PNT has been recognized in many studies [44, 45], but has not been widely compared to other non-invasive interventions. Other peri-tendinous injections can be combined with PNT, such as PRP or autologous whole blood, to enhance the induced regenerative result and promote tendon healing. As the non-invasive clinical approach and management of tendinopathy gain ground, the need for a preservative but definitive treatment arises. Subsequently, these combinations are currently subjected to extensive investigation [46].

Discussion

Tendon disorders represent many acute or chronic tendon pathologies, mainly caused by overuse conditions, where the tendon part of the muscle-tendon unit is imposed to excess force and stress. They represent one of the most frequent clinical diagnoses, accounting for 30% of all musculoskeletal consultations [47]. These injuries are usually encountered in athletes, presenting the highest prevalence in elite athletes, and different tendons are affected in distinct ways. Tendons of the rotator cuff, the long head of the brachial biceps, the extensors and flexors of the wrist, the thigh adductors, the posterior tibialis tendon, the patellar tendon, and the Achilles tendon are the districts most often involved [6], but every tendon can suffer damage.

Sport activity is the most recognizable risk factor for tendon injuries. However, other modifiable and not modifiable risk factors are taking part in developing tendon disorders. Age seems to be a

factor that influences the prevalence of tendinopathy since adolescents seem to be less affected compared to adults [48]. Sex is another factor influencing the presentation of specific tendinopathies in athletes [49]. Occupational exposure to intense-force repetitive movements combined with poor workplace ergonomics is a known risk factor affecting the upper extremities and predisposing to lateral epicondylitis [50].

Additionally, drugs can negatively affect tendinous tissue predisposing to injuries, such as corticosteroids, quinolone antibiotics, aromatase inhibitors, and statins [51]. Obesity is another risk factor since the increased weight puts excess force on the muscle-tendon units, leading to faster tendon wear. Lastly, numerous metabolic diseases can be presented with clinical symptoms of tendinopathy, such as chronic gouty arthritis, hypercholesterolemia, diabetes mellitus, and thyroid pathologies.

Surgery for chronic tendinopathy has presented inconsistent results and increased morbidity. Thus, it is not preferred as the go-to treatment choice [52], but it is preserved for patients that do not show improvement after six months with less invasive approaches. The routine use of NSAIDs and peri-tendinous corticosteroid injections are being re-evaluated since histologic examination of pathologic tendinous tissue has shown no signs of inflammation, which could benefit from anti-inflammatory agents. It is currently believed that these medications only offer transient pain relief with possible long-term adverse effects. Subsequently, new non-invasive tools are being investigated.

PRP, autologous whole blood and hyaluronic acid are materials proven effective in alleviating pain and histologically improving tendon injuries. Prolotherapy is a rapidly spreading approach, but its effectiveness is currently vastly studied compared to other interventions. The simple needle fenestration of the injured tendon has also shown promising results. It can be used as a standalone treatment or in combination with tested drugs and agents such as PRP and autologous whole blood.

The literature lacks extensive, high-quality double-blinded trials that will test the efficacy of different peri-tendinous injections and conclude which method leads to the best results in reconditioning the healing process, alleviating pain, and re-establishing range of motion. The treatment choice lies in the clinicians' empirically generated opinion, modified according to patients' characteristics and requirements.

Conclusion

Chronic tendon disorders are a frequent clinical entity encountered by the orthopaedic surgeon. Numerous non-invasive approaches exist, such as rest, training modification, NSAIDs, and abundant available drugs and agents for peri-tendinous injections. Tendinopathy is a non-inflammatory failed healing process that renders topical steroids inappropriate and harmful. New techniques have been presented, but further investigation is mandatory to show the best means available for non-invasive long-term management and even treatment of chronic tendon injuries.

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Cite this paper as

Gatos G, Brilakis E, Fandridis E, Megalooikonomos P, Kateros K, Oikonomou L. Peri-tendinous injections. An overview of agents and their efficacy. AOTH. 2025;76(1):33-40

AOTH

Review

Principles of musculoskeletal tumors biopsy

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Abstract

Biopsy remains a cornerstone in diagnosing musculoskeletal tumors, requiring meticulous planning and execution to ensure diagnostic accuracy while minimizing patient harm. Some benign lesions and hematological diseases can be diagnosed through imaging and laboratory results, negating the need for biopsy. However, if a biopsy is indicated, it should be performed in a specialized, multidisciplinary center where radiologists, pathologists, orthopedic surgeons, and oncologists collaboratively determine the most appropriate approach.

Several biopsy techniques are available, each suited to different clinical scenarios. Fine Needle Aspiration (FNA) is minimally invasive but limited by its inability to provide comprehensive histological data. Core Needle Biopsy (CNB) offers tissue samples sufficient for histological and molecular analyses and is nowadays the first-line choice due to its high diagnostic accuracy and low complication rate. Incisional biopsy, while invasive, is reserved for cases where extensive tissue sampling is required or the CNB is unsuccessful. Imaging guidance, such as ultrasound, fluoroscopy, or CT, can improve diagnostic accuracy and safety, especially for deep or complex lesions (13). A well-planned biopsy respects oncological surgical principles, avoiding contamination of surrounding structures and preserving future treatment options. Errors in biopsy technique can delay diagnosis, impact prognosis, and reduce the feasibility of limb-sparing surgery in malignant cases. Complementing traditional methods, liquid biopsies are emerging as a transformative tool in oncology. By analyzing circulating tumor cells (CTCs), tumor DNA (ctDNA), and extracellular ves-

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icles (EVs), liquid biopsies offer real-time insights into tumor behavior, metastases, and chemoresistance. These advancements not only enhance diagnostic precision and personalized treatment but also promise to reduce healthcare costs and improve patient outcomes.
This review highlights the importance of biopsy planning and selection in the context of musculoskeletal tumors, emphasizing the need for specialized, multidisciplinary input to optimize patient outcomes.

Keywords

Biopsy; bone sarcoma; soft tissue tumor; percutaneous; incisional; liquid biopsy

Introduction

A properly performed biopsy with subsequent histopathological examination presents the final and decisive step in the diagnostic chain of musculoskeletal tumors.

In knowledge of the patient's medical record and clinical examination as well as after the careful review of all necessary results of local imaging studies, and eventually of the systemic staging, a decision must be made, if a biopsy is necessary for the further treatment. Some benign lesions, inflammatory processes or even a underlying hematological disease can be diagnosed based on the imaging study (plain X-Ray, CT or MRI) or the laboratory findings (elevated CRP, abnormalities in full blood count), so that they don't require a histological confirmation[10].

A biopsy is a basic technical procedure, but if oncosurgical criteria aren't followed, it might negatively impact the patient's outcome, especially limb salvage in malignancy. 1982 Mankin et al. reported that biopsy associated complications occur 3 to 5 times less frequently in a specialized tumor center than in a less specialized treatment unit[2]. 2012 Schaser et al. estimated that the complication rate of a biopsy was about 9%, when performed in a tumor center while about 30% in non specialized centers[10]. Traina et al. noted that since there is no single standard biopsy approach for all these conditions and personal experience and judgment may influence biopsy decisions, it must be performed optimally in a center where experienced radiologists, pathologists, orthopedic surgeons, and oncologists (multi-disciplinary team) will preoperatively discuss the planning[7].

The purpose of a biopsy is to provide an accurate diagnosis causing minimal harm to the patient and his definitive operative treatment. The lesion should be sampled in a representative way without damaging neurovascular structures, contaminating uninvolved anatomical compartments or limiting definitive surgical treatment. Furthermore the samples should arrive in proper form to the pathologist, who has to determine if the lesion is benign or malignant, if the diagnosis is specific and if a grading of the tissue is possible, so that the treatment cascade can begin[2, 10].

Planning a biopsy

Most patients with a soft tissue tumor or bone lesion present with focal pain and/or swelling. The clinician should perform a thorough history and physical examination to evaluate important medical aspects such as the dynamic of tumor growth, the duration, the presence of pain or other side effects as well as inciting events (e. g. trauma).

In soft tissue tumors the imaging diagnostic approach usually starts with a high resolution ultrasound. If the findings are unclear or the mass is greater than or equal to 3 cm further evaluation through sectional imaging should be initiated. The best radiological study to assess a soft tissue mass is an MRI with IV contrast agent (e. g. Gadolinium). In addition plain radiographs provide important information regarding possible bone infiltration or erosions and can rule out a bone tumor mimicking

a soft tissue mass such as a prominent exostosis or a phlebolith within a hemangioma[5].

In bone tumors plain radiographs in 2 planes are usually the first diagnostic step. Many lesions such as non ossifying fibroma, fibrous dysplasia or osteoid osteoma present a pathognomonic image, so that a definitive diagnosis can be provided by a plain radiograph and a biopsy can be avoided[4]. MRI with IV contrast agent is the technique of choice when the finding is unclear and will provide additional information concerning the following biopsy. CT may also be necessary for the further planning (osteosynthesis, prosthesis etc.)

Under suspicion of bone metastasis or hematological disease (e. g. myeloma, lymphoma) further imaging including thorax und abdomen CT as well as appropriate laboratory tests should be additionally performed[10].

In any case a biopsy should be delayed until clinical evaluation is performed and the results of all imaging and laboratory studies are collected and discussed in an multi-disciplinary team, which has to clarify the followings:

1. Is biopsy indicated?
2. Which part of the tumor has to be biopsied? The biopsy should be representative of tumor histology.
3. Which type of biopsy is appropriate as to supply sufficient tissue to the pathologist?

Which is the most suitable surgical approach so that representative tissue in sufficient quantity can be yielded, avoiding vital structures like neurovascular bundles and without causing any further focal tumor cell dissemination or risking the definitive surgical tumor resection. It's crucial that the biopsy approach is discussed with the team, who will perform the actual appropriate resection of the tumor, since the biopsy tract is contaminated[1], it shouldn't violate more than one anatomical compartment and has to be resected en bloc with the underlying tumor.

Is an imaging technique for guidance necessary and if so, which one is the most appropriate? Palpable soft tissue masses, especially those that are superficial, may not require additional imaging techniques or can be easily evaluated with ultrasound guidance. For bone tumors, especially in long bones, fluoroscopy is indispensable. Lesions that are deeper and more difficult to access near vital neurovascular structures (pelvis, spine, etc.) may require CT guidance[3, 6, 13].

Biopsy techniques

The selection of the appropriate biopsy technique for the clarification of a musculoskeletal lesion is not a trivial decision. It should be as small as possible but as large as needed to provide an accurate diagnosis and it surely depends on the surgeon's experience, the pathologist's familiarity with the cytologic and histopathologic appearance of the different kind of tumors and not lately on the equipment capability of the center[4, 6]. Antibiotics should be stopped for at least 48 hours, ideally two to three weeks before the biopsy so intraoperative microbiological cultures (for differential diagnosis) can be reliable[11].

Excisional biopsy

An excisional biopsy is the complete surgical removal of the lesion. Only minor (< 3 to 5 cm) and superficial soft tissue lesions can undergo excisional biopsy. Since a malignancy prior to resection cannot be excluded, the surgical oncological criteria (margins, compartment separation etc.) should be considered, so that the definitive treatment can follow without the risk of contamination[4, 10]. Any soft tissue neoplasm located deep to the fascia is highly likely a sarcoma and should be biopsied prior to excision[12]

Fine needle aspiration (FNA)

A fine, hollow needle is inserted into the lesion directly to yield the sample. The role of FNA in musculoskeletal tumors diagnostic is very limited[12]. The procedure is mostly used for cytology examination of the aspirate (FNA Cytology) but there is rarely a possibility of histological tissue examination (FNA Biopsy). FNA's tumor diagnosis accuracy is frequently criticized. The published results vary from excellent to unreliable[8]. An ultrasound guidance may be used and several passes may be needed to increase the yield. It is the least invasive biopsy method, which can be performed even without a general anesthesia and has the lowest risk of tumor

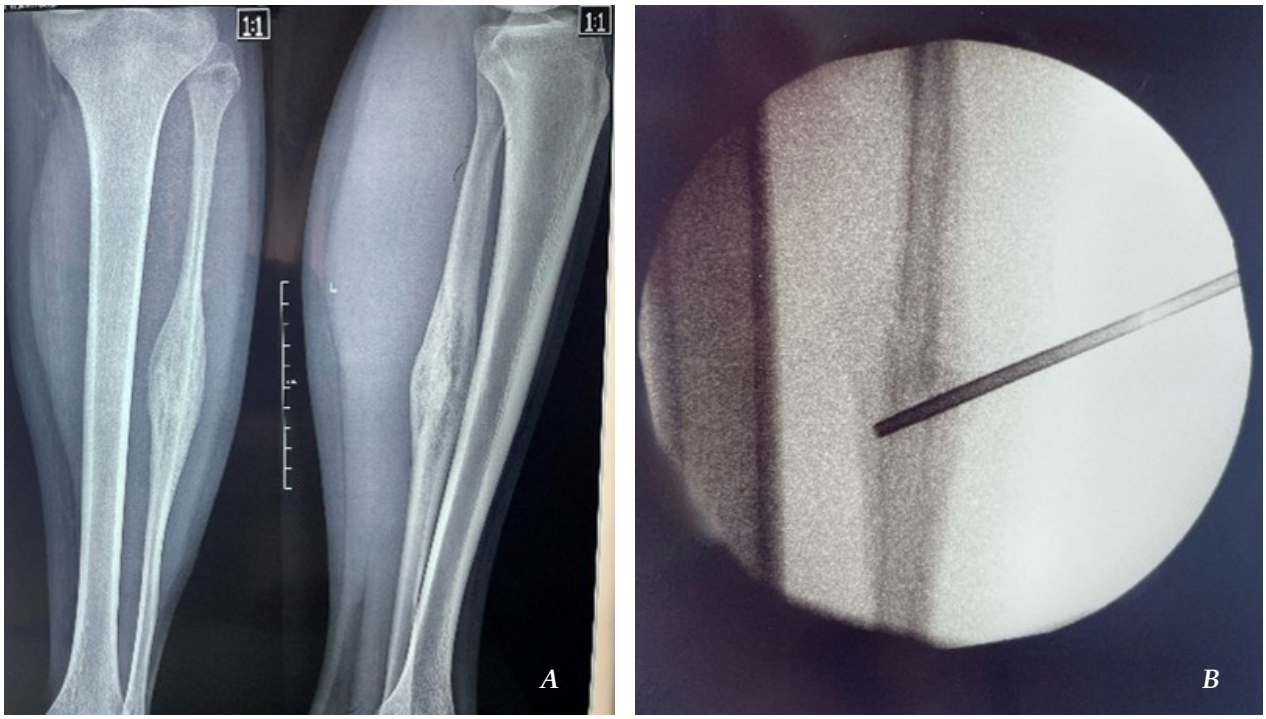

Figure 1a: *Ewing Sarcoma of fibula diaphysis links: Core Needle Biopsy (CNB) under fluoroscopy guidance.*

cell contamination of the needle tract. The primary drawback of FNA is that it only allows cytological evaluation of cells that are not structurally attached as aspirated, making it difficult to determine the histology type and grade[9].

The procedure has the highest accuracy in homogenous tumors and can be used particularly for documentation of metastases and local or distant recurrences, where the cytological findings can be compared with prior histology specimen[9, 12]. Layfield et al. reported that in 50% of all cases an FNA was followed by a Core Needle Biopsy (CNB) or incisional biopsy due to uncertain result[6].

Core needle biopsy (CNB)

Core biopsies provide a cylinder of tissue, which preserves the structural integrity of the tumor, enabling the potential for histological, immunochemical and molecular analysis and present therefore the gold standard procedure[12]. A 8-18 Gauge trocar is inserted via a small puncture wound into the mass directly or under guidance of ultrasound, fluoroscopy or CT[3, 13] (Fig 1). The site of insertion of the trocar (e. g. Jamshidi Trocar) should be in line of the possible definitive surgical incision since the biopsy tract has to be resected en bloc with the underlying tumor[1]. As this minimal tract is usually noticeable for 3-4 weeks postoperative, it should be marked (e.g. with indian ink) if the definitive surgery won't take place in the interim[4].

A minimum of three specimen for bone lesions and four for soft tissue lesions has been proposed4. Tissue samples should be taken from the periphery of the tumor due to the frequent presence of central necrosis[11]. In most cases a sufficient sample can be yielded, which can be used not only for rapid section diagnostic but also for immunohistology and molecular test such as PCR/FISH, so that an accurate diagnosis can be provided[12] (Fig 2).

CNB is usually performed as the first step in the invasive diagnostic cascade. An open biopsy is accomplished, when the sample is not representative. Especially under CT guidance CNB is very useful for deeper lesions near vital neurovascular structures, which require a pinpoint approach (pelvis, spine)[3, 9, 11, 13].

Less morbidity and fewer complications have been reported for CNB, ranking between 0-17%,

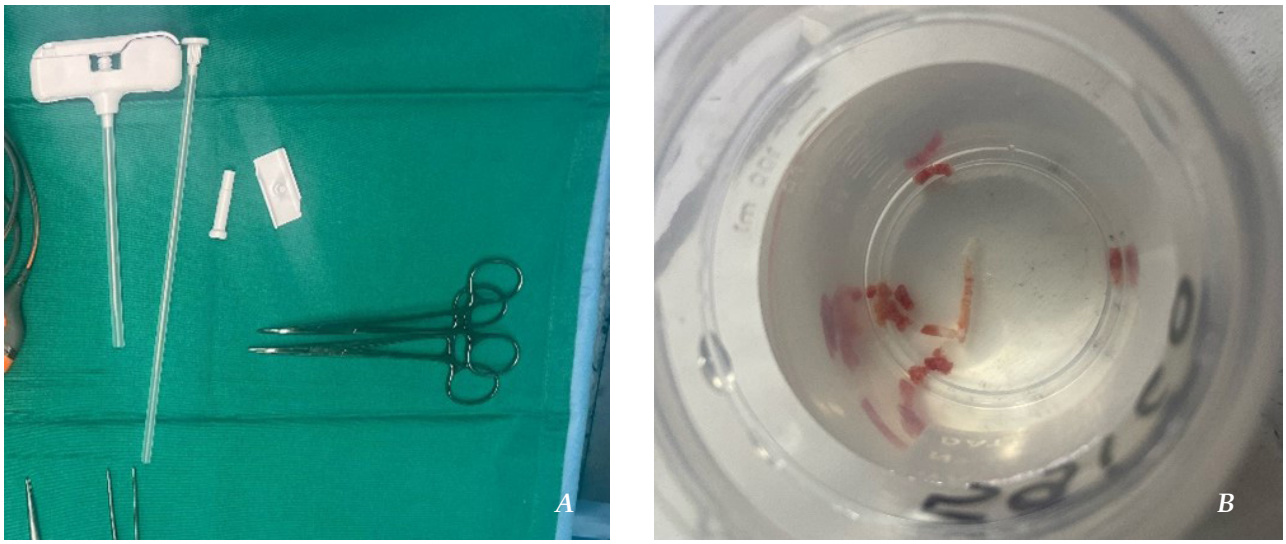

Figure 2: *a. Jamshidi Trocar is usually used for Core Needle Biopsy. b. Multiple cylinders of tissue obtained from different directions (fixation in formalin)*

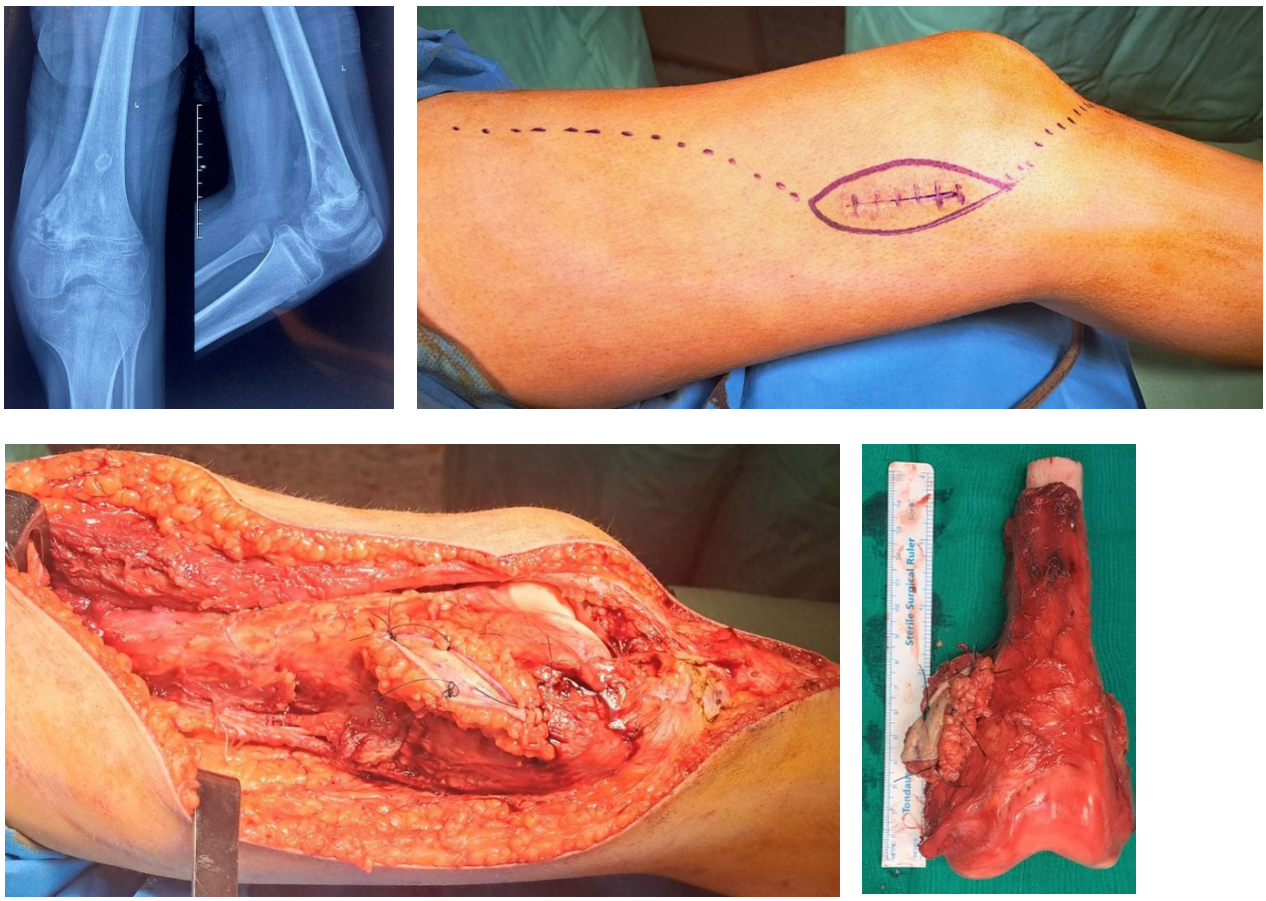

Figure 3: *Osteosarcoma of distal femur links: The definitive surgical incision (white arrow) is designed including the biopsy tract (yellow arrow), which is then resected en bloc with the underlying tumor.*

most commonly bleeding, hematoma and infection[9, 11]. Layfield et al. estimated that an incisional biopsy was performed in only 9,4% of all patients, who underwent CNB, while CNB demonstrates a slight superiority to FNA[6].

Incisional biopsy

Incisional biopsy has long been considered as the "gold standard". Certainly this is the method, which provides the largest sample of tumor tissue, allowing for higher degree of accuracy, but it also entails the greatest risk of local complications (bleeding, cell dissemination, limitation of the definitive surgery). Nowadays the incisional biopsy is indicated in difficult cases, when the imaging studies are not conclusive, the sample obtained from a less invasive method (FNA/CNB) is insufficient or larger specimen are required for further immunohistological or molecular examinations.

The sample should contain solid, vital tumor tissue of at least 1 cm^3 volume. When an incisional biopsy is performed with frozen section and the result is benign, a definitive resection can be completed in the same stage[9]. The biopsy incision must be previously discussed with the surgical team, who will perform the definitive surgery, so that the biopsy tract, which has to be completely resected en bloc with the tumor, won't influence the final surgical approach[1] (Fig. 3).

The most appropriate shortest approach (skin-lesion) should be chosen. The incision should be as small as possible and parallel to the longitudinal axis of the affected extremity. Transverse incisions are not recommended due to the need of a broader soft tissue removal during the final surgical procedure[12]. The approach should be through the muscle compartment over the tumor, no other compartment should be penetrated, so that a transfascial tumor cell contamination can be avoided. The biopsy shouldn't be in the immediate vicinity of neurovascular structures, which are vital for the extremity, or uninvolved joints. A bleeding or hematoma should be avoided too. If a tourniquet is used, a wrapping with an Esmarch bandage is contraindicated. The tourniquet should be released and precise hemostasis should be accomplished before would closure[2, 9, 12]. A drain is seldom necessary, but if needed, it should be placed closed in the line of the incision (<1 cm), since the drain sinus is regarded as contaminated and must be therefore removed en bloc with the surgical specimen and the biopsy tract[2, 9, 12].

In bone lesions with extraosseous tumor part, the soft tissue component is usually as much representative as the bony one. A penetration of the cortex can increase the risk of pathologic fracture, so that it should be performed mainly in purely intraosseous lesions[2, 7, 11]. Clark et al. reported that oblong bone windows with rounded ends provide the lowest risk of pathologic fracture. Increasing their width decreases the strength of the bone, while increasing their length does not[7].

Liquid biopsy

Liquid biopsy is a current and rapidly advancing aspect of medical diagnostics, especially in oncology. Derived from bodily fluids near malignant cells, it is particularly beneficial for tumors, that are difficult to access, as even minimally invasive biopsies can carry risks and often sample only a limited tumor area, which may not represent the entire tumor accurately.

Blood is the most commonly used fluid for liquid biopsies, though urine, cerebrospinal fluid, and saliva can also be useful depending on the tumor type. Blood-based liquid biopsies enable cancer profiling by analyzing circulating biomarkers (e.g. bone sialoprotein, osteoprotegerin), metabolites (e. g. pyridinoline) and three key biological components: circulating tumor cells (CTCs), cell-free circulating tumor DNA (ctDNA), and extracellular vesicles (EVs), such as exosomes[12].

A. Circulating tumor cells (CTCs)

Circulating tumor cells (CTCs) are rare tumor cells found in the bloodstream, first identified nearly 150 years ago by Ashworth, and now widely utilized in cancer diagnosis, prognosis, and monitoring. Advances in technologies like FDA-approved CellSearch and next-generation sequencing enable detailed analysis of CTCs, providing insights into the tumor's genetic and molecular characteristics. CTCs are particularly significant in metastatic

cancers, with higher counts associated with worse prognosis and specific metastatic patterns in cancers like breast, lung, and prostate. For bone sarcomas, such as osteosarcoma and Ewing sarcoma, CTC levels and characteristics predict metastasis, treatment response, and disease recurrence. Emerging research highlights combined CTC and circulating tumor DNA (ctDNA) analysis as a powerful tool for assessing metastatic progression and treatment outcomes across various cancer types[12].

B. Circulating tumor DNA

Circulating tumor DNA (ctDNA), primarily derived from apoptotic and necrotic tumor cells, provides valuable insights into tumor mutations, genomic alterations, and treatment needs, such as targeting the BRAF V600E mutation in various cancers. ctDNA analysis is especially useful in detecting metastatic disease, monitoring disease progression, and identifying minimal residual disease (MRD) for prognosis and treatment planning. Studies in breast cancer and non-small cell lung cancer (NSCLC) have shown a correlation between ctDNA levels and disease progression, including bone metastases. In bone sarcomas like osteosarcoma and Ewing sarcoma, ctDNA detection via next-generation sequencing has linked genetic alterations, such as TP53 mutations and EWSR1 fusion, to tumor burden, recurrence, and poor outcomes. Additionally, ctDNA levels reflect therapeutic responses, with potential for monitoring disease recurrence and guiding treatment in sarcoma patients. Further large-scale studies are needed to refine ctDNA's clinical utility[12].

C. Extracellular vesicles (EVs)

Extracellular vesicles (EVs) are lipid bilayer particles produced by cells, including cancer cells, and play key roles in tumor biology, diagnosis, and prognosis. These vesicles, which can encapsulate DNA, RNA, and proteins, provide stable molecular information and are particularly relevant in bone metastases, osteosarcoma, and Ewing sarcoma. Research highlights the potential of EV-derived biomarkers, such as mRNA and miRNAs, for early detection of bone metastases and cancer progression, as seen in studies on breast, lung, and prostate cancers. EV cargo has also been linked to therapeutic responses and clinical outcomes, as in osteosarcoma and Ewing sarcoma, where specific miRNAs and surface proteins serve as diagnostic and prognostic indicators. Despite challenges in cost and scalability, EV-based liquid biopsies offer significant promise for non-invasive cancer monitoring and personalized treatment strategies[12].

Despite their potential, liquid biopsies face several challenges hindering widespread clinical adoption. Variations in sample collection and processing can significantly affect results, with plasma preferred over serum to avoid contamination from other DNA sources. Lifestyle factors also impact cell-free DNA release, complicating data interpretation. Circulating tumor cells (CTCs) are rare and difficult to isolate, with current methods like CellSearch limited to DNA and immunofluorescence analyses, excluding RNA-based or functional studies. CTCs may not fully represent tumor heterogeneity, though new strategies like arterial blood sampling are being explored. Extracellular vesicles (EVs) also present unique challenges, including variability in isolation techniques and difficulty distinguishing tumor-specific exosomes. Implementing liquid biopsies requires specialized training, facilities, and expertise, alongside further research to standardize protocols and enhance accuracy[12].

Conclusion

Biopsy is the ultimate step in diagnosing possible malignant and unclear musculoskeletal lesions. Technical simple but conceptually complicated, it should be extensive discussed in a specialized multidisciplinary team after the completion of clinical evaluation and imaging studies.

Due to high accuracy and low complication rate the CNB is usually the first biopsy modality, followed by an incisional biopsy, when a precise diagnosis is not possible. The use of imaging guidance (ultrasound, fluoroscopy, CT) can increase the diagnostic accuracy and reduce the risk of complications. In any case biopsy should be performed in knowledge of the definitive surgical approach, always in line with the oncosurgical principles. An improper performed biopsy can not only lead to a

delayed and false diagnosis, but it can also jeopardize the limb salvage of the extremity and affect the patient's prognosis dramatically.

Liquid biopsies, either standalone or alongside traditional methods, hold transformative potential in oncology, offering real-time tumor monitoring and detection of metastases and chemoresistance. By combining tissue and liquid biopsies, healthcare costs can be reduced while improving patient outcomes and quality of life.

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Cite this paper as

Margariti R., Papavasiliou K., Kontogeorgakos V., Vekris M.D., Tsiridis E., Zambakides C. Principles of musculoskeletal tumors biopsy. AOTH. 2025;76(1):41-48.

AOTH

Review

Irrigation in open fractures: current concepts

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Abstract

Open fractures are most commonly the result of high-energy injuries. They present a higher rate of infection, when compared with closed fractures. On that account, the management of open fractures ought to be immediate and effective. Many steps are involved in this procedure, with one of them being wound irrigation. The research community has demonstrated a great interest in the best practices around the irrigation of open fractures. Nevertheless, a widely accepted protocol is yet to be determined. The timing of rinsing should be as early as possible, certainly in the first 24 hours after the injury. The quantity of fluids for irrigation is calculated, depending on the size of the wound, the extent of contamination and the coexistence of nerve or vascular damage. Low, non-pulsating pressure is ideal for most cases; high-pressure or pulse lavage can be reserved for highly contaminated wounds. Normal saline is a cost-effective, sterilized and isotonic solution, that is characterized by lower rates of infection, when compared with other fluid options and does not impede the wound healing process due to its low cytotoxicity. The existence of a standardized protocol for irrigation of open fractures is of great importance and, therefore, more relevant high-quality studies are needed.

Keywords

Open fractures; irrigation; saline; infection; review

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Introduction

Open fractures have always been considered, by their very nature, as an Orthopaedic and Trauma emergency. The incidence of open fractures is reported to be about 30.7 per 100,000 persons per year. [1] Most commonly, they are the result of high-energy injuries, such as crash accidents, falls from height and gunshots. [1] The risk for infection of open fractures in the United States of America can range from 18% to 30%. [2] Management of open fractures has evolved substantially throughout the years, considering that the treatment of choice during the American civil war was emergency amputation to diminish the risk of sepsis. [3] Nowadays, effective treatment of open fractures involves administration of intravenous antibiotics and tetanus-preventing measures ideally in the first hour, followed by immediate irrigation, debridement and fracture stabilization within the first 24 hours and wound closure within the first 7 days after the injury.[4] Irrigation and debridement of open fractures is a critical step of this protocol and therefore has received a lot of attention from the research community.[5] Timing, delivery pressure and type and quantity of irrigation fluids are factors that can vary a lot among surgeons.[1] This study aims to critically appraise the available literature for the best practices of irrigation procedures, by answering common questions that each surgeon faces when dealing with open fractures.

When should we irrigate?

Immediate and effective management of open fractures can be decisive for the patient's outcome.[6] Since the 19th century, the "common rule" of six hours was considered the gold standard; the first washing should ideally be done within the first six hours after the injury.[2,3] Of course, there is a plethora of different factors that should be taken into account before deciding the ideal irrigation plan, such as the size of the open wound and the extent of contamination.[1] (Fig. 1) A consensus among the authors and surgeons is still missing. According to several studies, the longer irrigation is delayed, the stronger the bonds of pathogens on bone and soft tissues become, and consequently, the harder their rinsing.[3,4] The benefits of early debridement and lavage, in the first six hours, have also been confirmed in experimental animal models.[3] On the other hand, there are publications available in the literature that report no differences in infection rates when comparing open fracture irrigation before and after the first six hours, as long as the 24-hour limit is not surpassed.[2,4,6]

Which is the ideal fluid-volume for irrigation?

The amount of fluids used to irrigate an open fracture is another important predictive factor of a patient's outcome.[1] There are no clear guidelines in literature, other than it ought to be plenty and, as a result, the amount is usually determined by the surgeon's judgment and clinical experience. It is common sense that the characteristics of an open fracture, such as the size of the exposed area, the contamination, the existence of debris, soil, dirt or foreign bodies and their attributes, such as material and size, can impact significantly the severity of the trauma and thus the need for a greater quantity of lavage solutions.[3,7] Furthermore, in the presence of coexisting disruption of noble elements, such as vessels and nerves, the surgeon in charge should adjust the plan of action accordingly, modifying the amount of irrigation fluids as well.[1,3,8] A very popular course of action among surgeons bases the quantity of fluids on the Gustilo-Anderson classification for open fractures; according to an easy rule of thumb, Gustilo-Anderson type 1 fractures should be irrigated with at least three liters of solution, type 2 with at least six liters, and type 3 with at least nine liters.[8,9] Unfortunately, there are no data in the literature proving the validity of this concept. Ultimately, the effect of the amount of solution, in reducing the microbial load of open fractures and, by extension, the patient's risk for infection, is still undetermined. (Table 1)

Which is the ideal pressure for irrigation?

Another topic of extended debate is the ideal fluid delivery pressure when debriding and irrigating an open fracture. The most convenient and cost-effective method, which is commonly preferred by surgeons in acute settings, involves the use of syringes or intravenous fluid bags with gravity flow to rinse the exposed area.[1,2] In recent years, new lavage devices have arisen and quickly gained field in the management protocols of open fractures. (Fig. 2) More specifically, these lav-

Figure 1a: *Gustilo IIIB distal femoral fracture*

Figure 1b: *Preoperative X-ray*

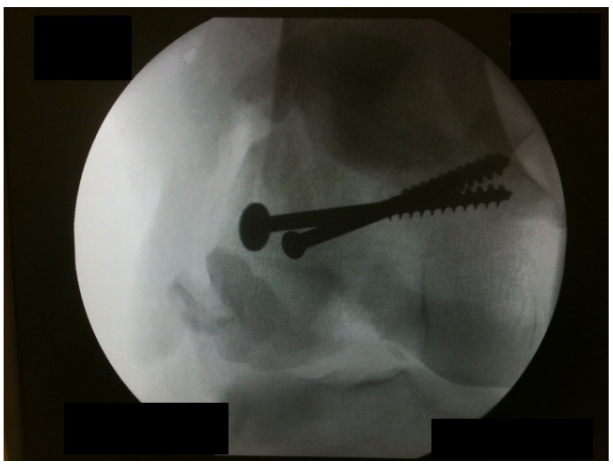

Figure 1c: *Intraoperative fluoroscopy of the screw fixation*

Figure 1d: *End-to-end wound closure*

Figure 2: *Mölnlycke® Pulsed Lavage system (source: https://www.molnlycke.co.uk/products-solutions/molnlycke-pulsed-lavage/)*

Table 1: Gustilo Classification (source: https://www.orthobullets.com/trauma/1003/gustilo-classification)

	I	II	IIIA	IIIB	IIIC
Energy	Low	Moderate	High	High	High
Wound size	≤ 1 cm	1-10 cm	usually >10 cm	usually >10 cm	usually >10 cm
Soft tissue damage	Minimal	Moderate	Extensive	Extensive	Extensive
Contamination	Clean	Moderate	Extensive	Extensive	Extensive
Fracture Comminution	Minimal	Moderate	Severe	Severe	Severe
Periosteal Stripping	No	No	Yes	Yes	Yes
Skin Coverage	Local coverage	Local coverage	Local coverage	Free tissue flap or rotational flap coverage	Typically requires flap coverage
Neurovascular Injury	Normal	Normal	Normal	Normal	Exposed fracture with arterial damage that requires repair

age systems offer adjustable delivery pressure and are usually powered by an external source, thus constituting an easy-to-carry and handle option when dealing with an open fracture. Additionally, irrigation fluids loaded in these lavage systems, can either be delivered at a constant or a pulsing pressure, offering the surgeon more versatility in his treatment plan of choice.[2,3]

The scientific community has shown a particular interest in these lavage systems and the impact of the variety of available settings on the different types of open fractures. Nevertheless, there is still controversy among authors regarding the classification of delivery pressures. However, a widely accepted theory categorizes lavage pressure from 1 to 10 psi as low, 11 to 19 psi as moderate, and pressure from 20 psi and above as high.[2,10] Several studies have concluded that irrigation of open fractures with high pressure increases the likelihood of infection, especially after the first 72 hours. Furthermore, high pressure can not only cause intramedullary dispersion of pathogen bacteria but also affect the natural bone healing process bone through changes in the trabeculae structure.[2,3] All these factors can potentially lead to late-onset infection, delayed union and even non-union.[2,3] Low-pressure rinsing is effective in most open fractures, without the drawbacks of high-pressure irrigation.[2]

On the contrary, some studies have demonstrated the beneficial effect of high-pressure irrigations in treating open fractures with extensive contamination, dirt, soil particles and large foreign bodies.[3,7] Finally, a randomized clinical trial concluded that irrigation of open fractures under low and high pressure did not differ significantly, as far as patients' quality of life 12 months after the incidence was concerned. It is also noteworthy that the quality of life remained lower when compared to prior injury in all the questionnaires that were assessed.[9]

A multicenter randomized study held in 2015 concluded that the use of constant and low pressure offers the best results in most cases, whereas pulse lavage with high pressure should be reserved for cases when irrigation and debridement are executed after the first six hours or in cases with extended contamination involving soil and dirt particles.[7] Additionally, the surgeon should always be alerted and prepared to shift to high pressure upon suspicion findings during irrigation, to avoid adhesion of pathogenic microorganisms on the bone and soft tissues that could lead to undesirable results. Interestingly, the same study also reported that conclusions from clinical trials regarding the irrigation protocols of open fractures do not always translate into significant differences in patient-important outcomes.[7]

What temperature should irrigation fluids have?

Fluids' temperature when rinsing open fractures is

usually not taken into consideration and its impact on the risk of infection is therefore underestimated.[1] Irrigation with warm solutions diminishes the incidence of hypothermia and the lengthening of hospital stay, whereas cold fluids mitigate bleeding, inflammation response and bacteria reproduction.[2] Data on the ideal temperature of irrigation fluids are insufficient and, for that reason, more primary research is needed to resolve this debate.

What type of solution should we use?

Multiple types of solutions are being regularly used in clinical practice for open fracture irrigation without unanimity among authors and surgeons.[2,3] Generally, the solution should be isotonic and non-toxic to the healthy tissues. Moreover, the fluids should be non-hemolytic and ideally free of minerals and chemicals.[2]

Sterile saline, sterile water for injection, tap water

Sterile saline is a mixture of sodium chloride and water. It is a cost-effective, isotonic fluid with low cytotoxicity and thus is considered the gold standard for irrigation among most surgeons.[2,3,7] The FLOW trial concluded that normal saline offered lower rates of infection when compared to saline water mixed with castile soap.[7] Water for injection is another sterile alternative, but the existence of minerals inside renders it hypotonic.[8] Tap water is not only hypotonic but also not disinfected. The use of hypotonic fluids in large volumes can potentially lead to intracellular damage and hinder the natural wound-healing process.[2] Nevertheless, studies have proven that tap water offers similar rates of infection when compared with saline solutions and therefore should be considered a safe alternative in the absence of other sterile options.[2]

Antibiotics

Antibiotic irrigation fluids can be beneficial in preventing the adhesion of microorganisms on bone and soft tissues.[1] However, the results from available data, including in vitro and animal studies, are ambiguous.[3] Some authors have concluded that the application of antibiotics on open trauma diminishes the number of pathogens.[3] On the other hand, antibiotics can impede normal cellular function and disrupt, as a result, the wound-healing process.[2,3] Moreover, they are more costly than sterile saline or castile soap and can trigger allergic reactions that demand urgent treatment.[2] Finally, rinsing with antibiotic solutions is important to be conducted as soon as possible after the injury, as their anti-microbial properties become less potent after the formation of bacteria biofilms.[2,3]

Castile soap

Castile soap is the most commonly used product in the surfactants category. Unlike antibiotics, they owe their anti-bacterial characteristics to micelles that bind with pathogens and are rinsed away from the trauma altogether.[2] Castile soap mixtures offer better results in the irrigation of open fractures compared to antibiotic and antiseptic solutions, despite not being sterilized.[3] Nonetheless, the re-operation rate is higher compared to saline solutions.[7]

Antiseptics

Antiseptics are effective on most types of pathogens, including bacteria, viruses and fungi.[3] The most popular antiseptics being used are povidone-iodine, chlorhexidine, hydrogen peroxide and benzalkonium chloride. It is generally recommended to avoid scrubbing open fractures with antiseptic solutions.[2] Povidone-iodine in small concentrations is non-toxic for the tissues but should be avoided in patients with thyroid diseases. Hydrogen peroxide can break down into oxygen gas and potentially cause gas embolism.[2] Overall, despite their beneficial properties in reducing the microbial count, they are usually not the first choice of surgeons due to their possible side effects and cytotoxicity that can either affect wound healing or lead to systematic complications.[2,3]

Conclusions

Irrigation and debridement of open fractures are of great importance for reducing the risk of infection.

Timing is crucial and for that reason, irrigation should be conducted as soon as possible after the injury, definitely in the first 24 hours.

"The more the better" is a safe practice concerning the quantity of fluids. Gustilo-Anderson grade 1 should be rinsed with at least three liters of fluids, grade 2 with at least six liters and grade 3 with at least nine liters, respectively.

As far as pressure is concerned, most open fractures can be irrigated effectively with low pressure, by using intravenous bags with gravity flow or syringes and needles. High-pressure and pulse lavage systems should be utilized in greatly contaminated wounds with dirt, soil or foreign bodies.

Solutions' temperature is an under-evaluated variable in the management of open fractures that could be proven to play a significant role in patients' outcomes in the future.

Several types of fluids have been thoroughly studied. Sterile saline solutions are cost-effective options that succeed in adequately irrigating most open fractures, mitigating the risk of infection. Solutions with antibiotics, castile soap or antiseptics can also be used, always taking into consideration the possible cytotoxic and wound-healing side effects.

There are multiple factors in the irrigation process of open fractures. Nevertheless, a widely accepted algorithm is yet to be determined. Consequently, the surgeon in charge should always assess each case independently and modify the variables accordingly, based on both the latest research studies and his clinical experience as well.

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Cite this paper as

Savvidis M.S., Pegios V, Kouzelis A, Kokorogiannis K, Brilakis E, Badekas A. Irrigation in open fractures: current concepts. AOTH. 2025; 76(1):49-54.