Clinics in Oncology

Review Article
Published: 18 Dec, 2023

Surface Osteosarcomas a Reclassification of the Lesions

Nouri H[1], Kacem MS[2], Abid L[3] and Ben Maitigue M[4]*

[1]Private Hospital, Centre Urbain Nord Tunis, Tunisia

[2]Department of Emergency, Kassab's Orthopeadic Institute, Tunisia

[3]Department of Pathology, Kassab's Orthopeadic Institute, Tunisia

[4]Department of Orthopedic Surgery, Sahloul Hospital, Tunisia

Key-Points

1. Surface osteosarcomas are rare subtypes of osteosarcoma characterized by their development on the surface of cortical bone.

2. According to WHO 2020 classification, surface osteosarcomas include three entities: Parosteal osteosarcoma, periosteal osteosarcoma and high-grade surface osteosarcoma.

3. Parosteal Osteosarcoma (POS), is the most frequent subtype:

- It originates from the outer fibrous layer of the periosteum.
- It has a melon shape appearance pasted on the surface of long bones from which it's separated by a radiolucent line. It's mainly metaphyseal.
- The classic Parosteal Osteosarcoma (cPOS) has a low grade of malignancy and is mainly fibroblastic.
- Surgery is the unique treatment of cPOS.
- Sometimes cPOS progresses to a high-grade osteosarcoma *via* dedifferentiation.
- Dedifferentiated POS (DPOS) has a high propensity to metastasize and it's treated by a combination of wide resection and adjuvant chemotherapy.
- POS are characterized genetically by the amplification of MDM2 and CDK4.

4. Periosteal osteosarcoma (PerOS):

- It originates from the germinal inner layer of the periosteum.
- It has a saucer shape appearance and it's mainly located in the diaphysis of long bones.
- It is mostly chondroblastic and has an intermediate grade of malignancy.
- Surgery with wide resection is the treatment of choice for PerOS.

5. High Grade Surface Osteosarcoma (HGSO) is the rarest subtype:

- It includes all osteosarcomas located on the surface of the bone and that are of high grade of malignancy.
- It originates either from the inner layer or the outer layer of the periosteum.
- Unlike POS or PerOS, HGSO doesn't have specific radiographic or histological features.
- It has the worst prognosis among all subtypes.
- It's treated by a combination of wide resection and adjuvant chemotherapy.

Keywords

Parosteal osteosarcoma; Periosteal osteosarcoma; High grade surface osteosarcoma.

Introduction

Osteosarcoma is a primary bone malignancy characterized by malignant cells of mesenchymal origin depositing immature osteoid matrix [1]. The spectrum of lesions is very wide; they can be distinguished either by their grade of malignancy, the differentiation of neoplastic cells or even

OPEN ACCESS

Correspondence:
Habib Nouri, Private Hospital, Centre Urbain Nord Tunis, Immeuble Palace Centre Urbain Nord. 1082 Tunis, Tunisia

Received Date: *18 Nov 2023*
Accepted Date: *11 Dec 2023*
Published Date: *18 Dec 2023*

Citation:
Nouri H, Kacem MS, Abid L, Ben Maitigue M. Surface Osteosarcomas a Reclassification of the Lesions. Clin Oncol. 2023; 8: 2036.

ISSN: 2474-1663

according to their location in the bone. A few entities arise on the cortical surface thereby they are called surface osteosarcomas.

Surface osteosarcomas are subdivided into three patterns: Parosteal Osteosarcoma (POS), Periosteal Osteosarcoma (PerOS) and High-Grade Surface Osteosarcoma (HGSO) [2]. They represent respectively 5%, 1.5% and 0.5% of all osteosarcomas [1,3]. POS is characterized by a low grade of anaplasia. PerOS has an intermediate histological grade of malignancy. HGSO is an entirely high-grade tumor.

Surgical resection with wide margins is the cornerstone of the treatment of surface OS. These lesions are less sensitive to chemotherapy than conventional high-grade OS. It's advisable to use chemotherapy only for high grade lesions as an adjuvant treatment. Low and intermediate grade lesions have a good prognosis with up to 80% five-year survival rate. However, high grade lesions have a low survival rate [4].

Pathogenesis of Surface OS

Understanding the histology of the periosteum helps decode the pathogenesis of surface OS. The periosteum consists of two layers [5].

- The outer fibrous membrane: composed of mostly collagenous hypocellular connective tissue.
- The inner cellular layer: Also called the cambium layer, made up of osteoprogenitor cells which are multipotent stem cells that can undergo mitotic division and differentiate into osteoblasts. This layer is a highly vascularized structure and it's known as the osteogenetic layer.

POS originates from the outer fibrous layer. However, PerOS and HGSO originate from the inner cellular layer. This is consistent with radiological and pathological features as we'll see below.

Parosteal Osteosarcoma (POS)

Epidemiology

POS is the most frequent surface osteosarcoma subtype but it remains rare representing less than 5% of all osteosarcoma [6,7]. POS occurs in young adults with a mean age of about 25 years [7,8], which differentiates it from the common form that occurs in the second decade of life. It affects both sexes with a slight female predominance [6].

The low grade well differentiated POS is the classic type (cPOS) and the most common one. Sometimes, cPOS gets dedifferentiated and develops more aggressive behavior. It's then called Dedifferentiated POS (DPOS) [9]. Actually, the real incidence of dedifferentiation is underestimated since some lesions seen at an advanced stage are misdiagnosed as conventional OS or confused with HGSO.

Localization

POS has a predilection for the posterior aspect of the distal femoral metaphysis. The 2 main other locations are the proximal tibia and proximal humerus. Diaphyseal location is possible but uncommon [6,8,10,11].

Clinical findings

cPOS is a very slow growing lesion. Patients usually complain of long history of painless lump or an articular discomfort related to a joint stiffness, mainly knee flexion contracture. The tumor can even be diagnosed incidentally [6].

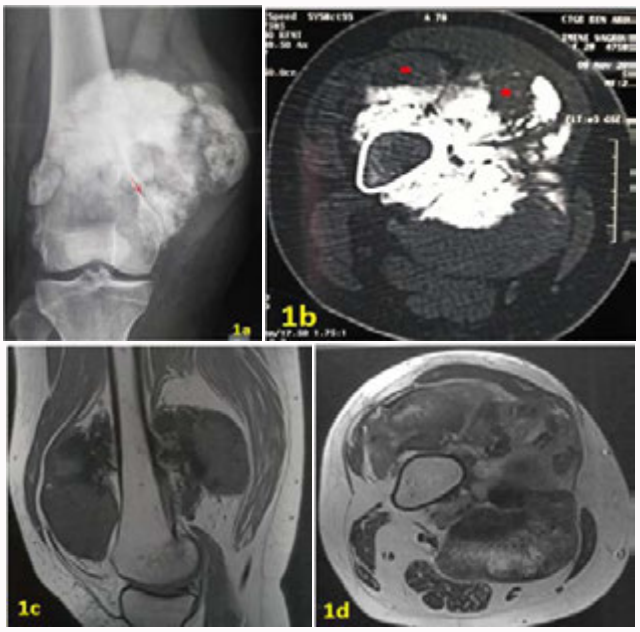

Figure 1: cPOS in a 28-year-old patient.
Figure 1a: AP X-ray of the right knee shows an ossified tumor on the surface of the femur. A radiolucent cleavage plane (arrow) is seen between the tumor and the underlying cortex.
Figure 1b: Transversal CT image showing an ossified lesion developed at the surface of bone cortex. Some areas are not ossified (red point).
Figure 1c, 1d: MR Images showing a broad implantation base of the tumor and the absence of medullary extension.

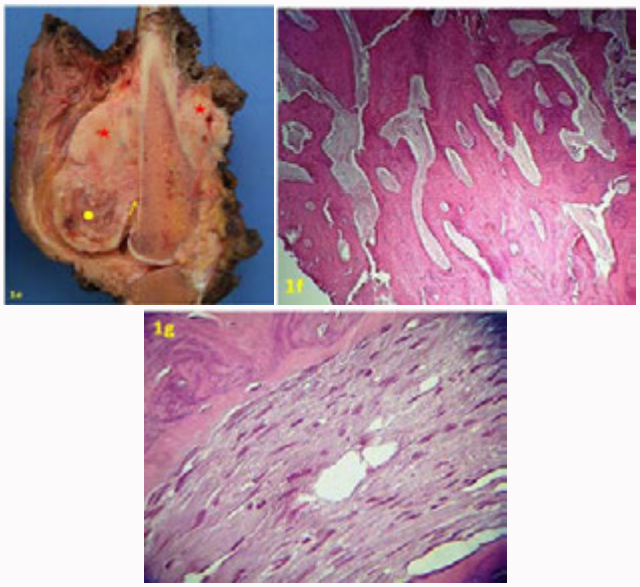

Figure 1e: Gross specimen showing a large mass pasted on the underlying cortex with no medullary invasion. The cut surface displayed a heterogeneous appearance with ossified (red stars) and fleshy areas (yellow circle). A thin lucent line (yellow arrow) is seen between the tumor and bone corresponding to the radiolucent cleavage plane seen on X-ray.
Figure 1f: Photomicrograph showing an extensive bone formation arranged in trabecular streamers with fibroblastic stroma (original magnification x40; H-E stain).
Figure 1g: The tumor is consisting of spindle-cell with minimal atypia between the bone trabeculae (original magnification x125; H-E stain).

When the tumor is more symptomatic with a painful rapid growing mass, dedifferentiation must be suspected.

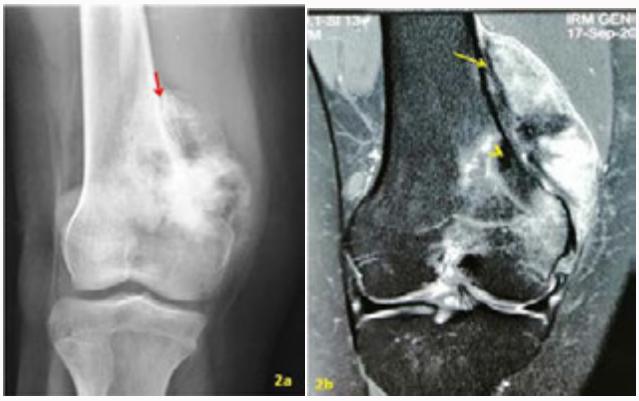

Figure 2: DPOS in a 26-year-old female.
Figure 2a: AP X-ray of the right knee shows an ossified peripheral tumor in the distal metaphysis of the femur with a lucent cleavage plane at its edge (red arrow).
Figure 2b: MRI coronal DP fatsat. The tumor is developed on the surface of the periosteum (yellow arrow). There's a focal intramedullary extension (arrow head).

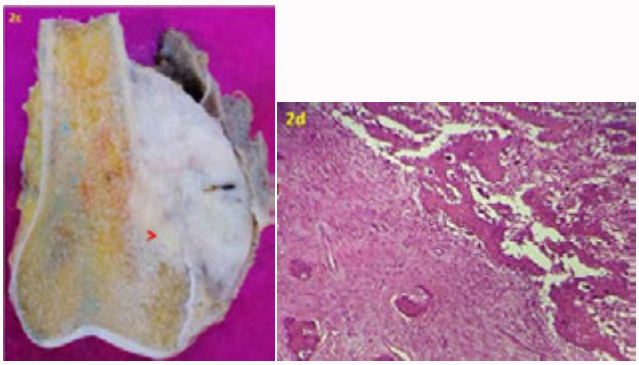

Figure 2c: Gross specimen showing a large, gritty white mass pasted on the underlying cortex with medullary invasion (arrow head).
Figure 2d: Photomicrograph showing an area of low-grade parosteal osteosarcoma (left side) adjacent to an area of conventional high-grade osteosarcoma with the fine lacelike osteoid and pleomorphic spindle-cell. The two components are separated by a sharp transition zone (original magnification, x80; H-E stain).

Radiological features

On the X-ray, POS classically appears as a "melon-shaped" mineralized tumor pasted on the cortex of the host bone. It often manifests as a large mass of about 5 cm to 10 cm or even larger with a broad base and a lobular morphology [8]. The tumor is typically separated from the bone by a radiolucent cleavage space representing the interposition of the periosteum between the cortex and the mass [2,12] (Figure1a, 2a).

CT scan confirms the surface ossified mass and is useful to detect cortical involvement and presence of medullary invasion (Figure 1b). MRI is important to assess local extension and medullary involvement (Figure 1c, 2b, 2c).

Medullary invasion is correlated with grade of malignancy for some authors [9,13] and can be therefore a distinctive feature between cPOS and DPOS. We have reported in a previous study that invasion of the medullary canal was more frequent in DPOS than in cPOS (100% *vs.* 25%) but it is debatable [2]. Bertoni [9] studied the meaning of radiolucencies in parosteal osteosarcomas and concluded that the presence of deep intralesional radiolucencies within a parosteal osteosarcoma strongly suggests possible dedifferentiation.

Histology

In macroscopy, POS appears as a hard ossified and lobulated mass arising from the cortical surface of the bone and attached to it with a broad base (Figure 1d, 1e, 2d). The cleavage space separating the lobulated mass from the periosteum which is seen on X-rays attests to its outer layer origin [6].

Microscopically, the cPOS is composed of mature trabecular bone associated to a fibroblastic spindle cell stroma [4]. This tissue has moderate cellularity and shows minimum cytological atypia and rare mitotic activity (Figure 1f, 1g).

The presence of a component of higher grade in POS attests of dedifferentiation (Figure 2e). The high-grade component can be fibroblastic, osteoblastic or chondroblastic.

Genetics

POS is characterized by a high rate of MDM2 amplification (Chromosome 12q13-15) in up to 83% of tumors [14,15]. CDK4 gene is located in the same region and is often co-amplified and over expressed in 67% of POS. As the percentage of CDK4 and MDM2 amplification in POS is much higher than in conventional OS, most likely the MDM2/CDK4 amplified high-grade tumors represent a progression from a low-grade POS.

Differential diagnosis

On X-rays the POS is frequently confused with other ossified bone surface lesions especially myositis ossificans and osteochondroma [16].

Upon histological examination, cPOS with its well differentiated and parallel bone trabeculae is classically overlapped with a callus of fracture, fibrous dysplasia or Paget's disease [5].

Discrimination of DPOS from conventional high-grade OS in the absence of cPOS features is challenging especially when there is involvement of the medullary canal. In these cases, Immunohistochemistry (IHC) can be helpful with the use of MDM2 antibodies. Since conventional OS is mostly negative to MDM2, positive tumors can be considered as a progression from a cPOS. FISH for MDM2 amplification is more sensitive and specific than IHC [17].

Prognosis

cPOS has a good prognosis. Survival rate is as high as 100% when tumor is resected with safe margins [8,9]. Local recurrences are usually secondary to intralesional or marginal resection and metastases are exceptional (less than 5%) [9].

The most important risk of cPOS is progression in the grade of malignancy called dedifferentiation which can be detected either at the time of the initial diagnosis (synchronous: 2/3 of cases) or at the time of the recurrence (metachronous) [9]. The risk of dedifferentiation is not well evaluated in the literature. Jelinek et al. [18] analyzed sixty parosteal osteosarcomas and they found that between 22% and 64% of parosteal osteosarcomas may contain components with a higher degree of anaplasia.

In patients with DPOS, the metastatic rate is much higher (30-50%) [9]. Survival data for DPOS are discordant in different series. Some studies have demonstrated poor overall survival [19], while

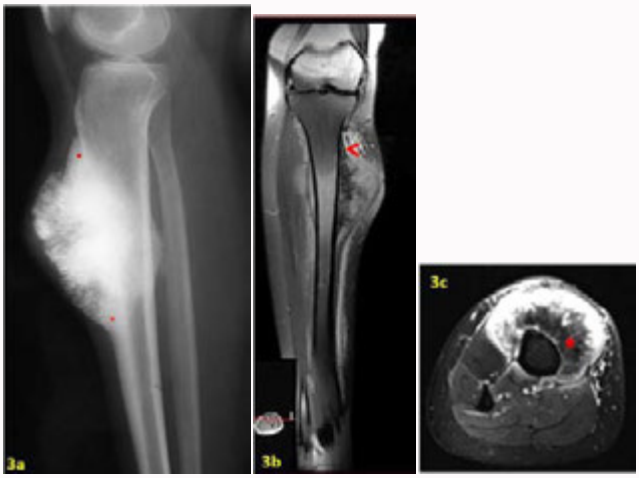

Figure 3: PerOS in a 16 years-old female.
Figure 3a: Lateral view X-ray of the leg showing an ossified peripheral mass on the tibial shaft with a thickening at the edge (red point) and a perpendicular periosteal reaction in the center.
Figure 3b, 3c: T1 FAT SAT after Gado MRI showing that the mass is developing under the periosteum (arrow head) that lifts it. Note the absence of medullary extension. The hypointensity signal (red star) indicates the cartilaginous matrix.

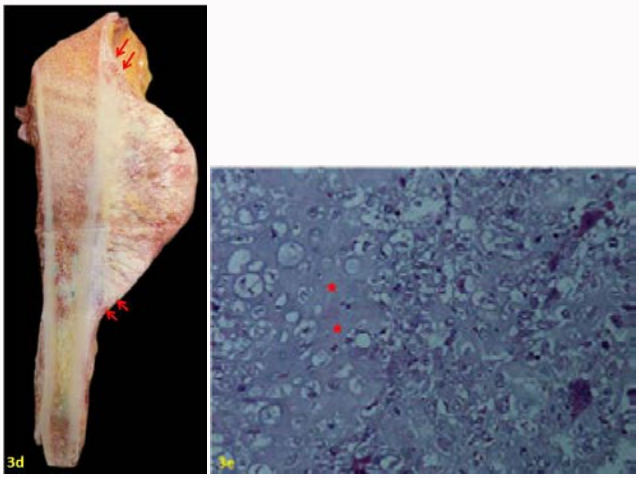

Figure 3d: The patient had wide resection. Note that the tumor develops under the periosteum (red arrows) and the medullary canal is tumor free.
Figure 3e: Lower-power photomicrograph showing a periosteal osteosarcoma. The tumor is predominantly cartilaginous with lace-like osteoid production (red stars) (hematoxylin and eosin, 40).

other studies have shown a better prognosis [9].

Treatment

Surgery is the main treatment of cPOS. In cases without medullary involvement, unicortical tumor resection with marginal margins can be a safe procedure when it is feasible [1,20].

However, DPOS needs to be treated more aggressively. Wide margins are mandatory to avoid local recurrence. Taking into account the high metastatic risk, chemotherapy is indicated. However, its efficacy is debatable. Sheth et al. [20] found that neoadjuvant chemotherapy may improve the clinical outcome. In other studies, the clinical importance of chemotherapy associated with wide surgical resection is not clear [21]. Due to the poor response to chemotherapy which associated with a high risk of tumor progression, it is recommended to use chemotherapy as adjuvant after surgery for DPOS [4].

Periosteal Osteosarcoma

Definition

Periosteal Osteosarcoma (PerOS) is an intermediate-grade OS mainly chondroblastic, arising on the surface of the bone and originating from the inner germinative layer of the periosteum [22]. Although the lesion was first recognized by Ewing in 1939, the term "Periosteal Osteogenic Sarcoma" and its distinct clinicopathological description was given by Unni et al. [23-25].

Epidemiology

This rare tumor represents less than 2% of all osteosarcomas. It occurs slightly higher in males and in younger patients compared to POS [22-27].

Localization

This neoplasm is usually located in long bones. Its preferred sites are the tibia and the femur. It evolves in the diaphysis and has rarely a metaphyseal location [28].

Symptoms

The prominent clinical symptom is swelling. Growth rate is usually slow. The pain, when present, is generally moderate [28].

Radiological features

In radiography, PerOS has typically a saucer shape appearance. We observe a broad based fusiform soft tissue mass. The cortex is thickened at the periphery by a solid or lamellated periosteal reaction with occasionally a Codman triangle [4,29]. In the center, there is a scalloping of the cortex associated to periosteal spicules perpendicular to the long axis of the shaft (Figure 3a).

The CT is useful to focus on the cortex erosion and the periosteal reaction. MRI is important to detect medullary involvement and to evaluate soft tissue invasion [28,29]. We can easily see the periosteum covering the soft tissue mass which is consistent with the origin of this tumor (Figure 3b).

Histology

Macroscopically, PerOS has a small to moderate size and its outer surface is well demarcated from the soft tissues by the periosteum [1,28] (Figure 3c, 3d). The typical histological feature is large irregular lobules of chondroblastic tissue with small areas of osteoid formation (Figure 3e). The tumor is graded 2 or 3 when it is chondroblastic and at least 2? In osteoblastic or fibroblastic differentiation [22,30].

Genetics

Recent findings have highlighted the genetic origins of PerOS. A mutation in at least one allele of the TP53 gene (exon 8) which is responsible for DNA repair and apoptosis has been found. This mutation leads to the inactivation of this gene *via* MDM2 protein regulation which directs it to the ubiquitin-mediated degradation pathway which is in turn linked to Wnt signaling [28].

Differential diagnosis

1. HGOS: It has a more aggressive course. Tumor cells are grade 3 or 4 in Broder's classification. However, in chondroblastic differentiation, only grade 4 tumors are considered as HGSO [1,19].

2. Periosteal chondrosarcoma: The location is different and is

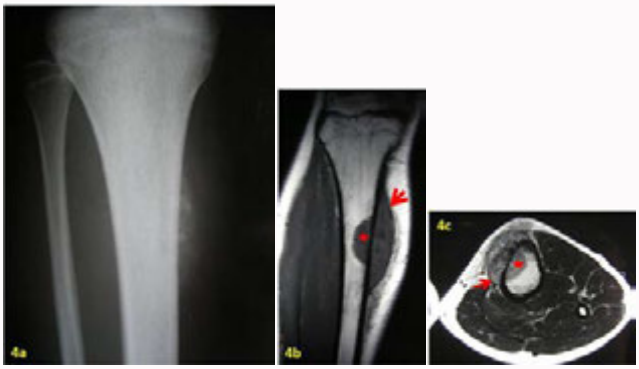

Figure 4: High grade surface osteosarcoma in a 17-year-old female.
Figure 4a: AP X-ray of the right tibia: soft tissue mass on the surface of the tibia moderately mineralized giving a fluffy immature appearance.
Figure 4b, 4c: MRI showing that the tumor mostly developed on the bone surface with focal medullary canal extension (star). Note that the tumor is lifting the periosteum from the cortical bone (red arrows).

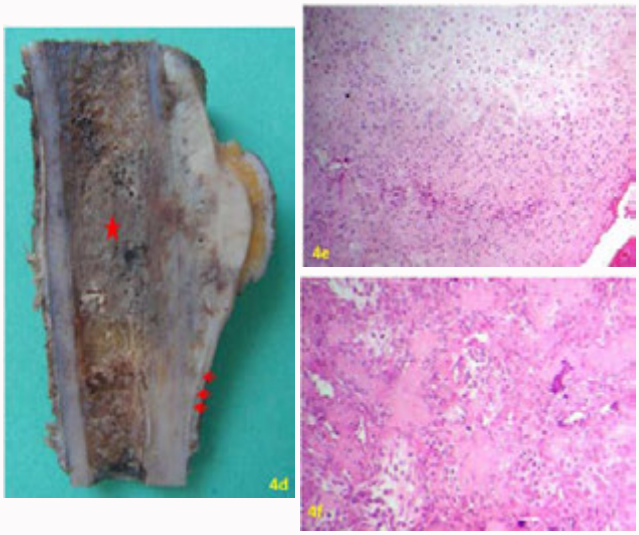

Figure 4d: Gross specimen showing a white to grayish tumor that develops in the deeper part of the periosteum and shows lifting of the periosteum (red arrows). Large bone marrow invasion (red star).
Figure 4e, 4f: HGSO with predominant chondroblastic differentiation.

usually metaphyseal. It is composed of malignant cartilage without any osteoid producing cells [31].

3. POS: Imagery is determinant for making the difference between the two entities [1].

Prognosis

Cesari et al. [22] reported a 10 YOS rate of PerOS of 84% indicating that this tumor has a better prognosis then HGSO but worse than POS.

PerOS has a low propensity to metastasize; however inadequate surgical margins (marginal or intralesional) lead to local recurrence [1].

Treatment

The treatment consists of wide resection to achieve safe margins. In literature, some authors opted for a partial resection of the cortex for small limited lesions [4]. Amputation can be discussed for expanded tumors or in case of recurrence with medullar involvement [28].

Chemotherapy has been occasionally prescribed but has not shown any benefit in this intermediate grade OS [22].

High Grade Surface Osteosarcoma

Definition

HGSO is the rarest subtype of surface osteosarcomas [19,32]. This lesion was first described by Francis et al. [33] in 1964 but it was not until 1984 that Wold et al. [34] reported the first series of this extremely rare tumor.

HGSO originates either from the inner or the outer layer of periosteum. Apart from its surface location, it does not differ histologically from conventional intramedullary osteosarcomas [34].

Epidemiology

HGSO accounts for less than 0.5% of all osteosarcomas. Here also, we think that the real number of HGSO is underestimated, since cases that progressed largely in the medullary canal are undistinguishable from conventional high-grade OS. The mean age of onset is around the second or the third decade and men are affected more frequently than women [19].

Localization

The most frequently involved sites are those of POS and PerOS, namely the mid shaft of the femur and the tibia and the distal femur [35-37].

Symptoms

HGSO is more aggressive than other patterns of surface osteosarcomas leading to rapid progression of the disease. The mean duration of symptoms is 6 months [36]. Pain and swelling are the most frequent symptoms.

Imaging

HGSO is described in the literature as a dense to moderate mineralization with a fluffy immature appearance (Figure 4a) [19]. In cross-sectional studies, the tumor usually involves on average half of the circumference of the hosting bone (Figure 4b). MRI is very helpful to show the lifting of the periosteum by the tumor (Figure 4b, 4c). An extension to the medullary canal is observed in about half of the cases [29] (Figure 4b-4d). In these cases, involvement of the medullary canal should be limited unless classic high-grade OS is considered.

Histological features

Basically, the histological features are those of conventional OS. The tumor exhibits frankly malignant spindle cells with atypia graded 3 or 4 according to Broder's classification (Figure 4e). Tumor cell differentiation is either osteoblastic, fibroblastic or chondroblastic (Figure 4f) [9,38]. In the latter form, tumor cells should be graded 4 unless the tumor is classified as PerOS.

Genetics

The genetic alterations observed in HGSO are very heterogeneous and findings have been largely inconsistent [15].

Prognosis

HGSO has the worst prognosis of the three subtypes, even worse than conventional intramedullary OS. The 5-year survival rate was reported to be as low as 37.6% [36]. One of the reasons for this poor survival rate is the high propensity of this tumor to metastasize [1,36].

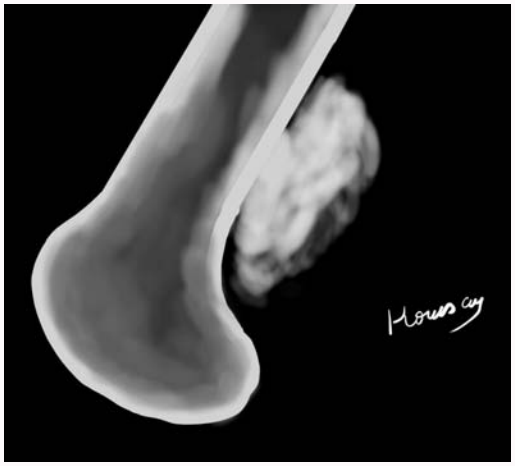

Figure 5: Typical radiographic appearance of parosteal lesions.

Figure 6: Typical radiographic appearance of periosteal lesions.

Deng [36] reported a rate of metastases of 70%.

Treatment

Surgery is the cornerstone of the treatment of HGSO. Resection of the tumor with wide margins is necessary to avoid local recurrence [36]. Even though clinical studies have failed to demonstrate any benefit of chemotherapy either in disease free survival or in overall survival [37], systemic therapy is recommended due to the high risk of distant metastasis in HGSO. The chemotherapy regimen is similar to that of conventional OS and it's administered as adjuvant to surgery [39].

Reclassification of the Lesions

HGSO seems to be the least defined lesion of the three subtypes. It includes all the tumors that are of a high grade and are located on the surface of bone regardless of their:

- **Clinical behavior:** Some patients included in the series of Stall [37] had a duration of symptoms of 10 years which is inconsistent with a high-grade sarcoma.
- **Origin:** HGSO can originate either from the inner layer or the outer layer of the periosteum [31].
- **Radiological appearance:** HGSO doesn't have proper radiographic features. Cases illustrated in the literature are highly evocative of either POS or PerOS [31,35-37].
- Histological differentiation.

We think that the current classification of HGSO includes a certain number of DPOS with a misdiagnosed cPOS component. Indeed, some metachronous DPOS are entirely of high grade.

Based on the origin of the tumor and hens its radiological appearance, we think that there are actually only two entities of surface osteosarcomas:

- In one hand, we have tumors originating from the outer layer of periosteum called the parosteal osteosarcomas. They are grossly recognized on imaging as a "melon shaped" ossified mass pasted on the bone surface and separated from it by a radiolucent line (Figure 5). With the progression of the disease, the tumor can lose some of these radiographic features and exhibit more aggressive behavior according to its grade of malignancy. Histologically, the cPOS is a low-grade tumor and the DPOS is a high grade one. These tumors are MDM2 and CDK4 positive.
- In the other hand, we have tumors originating from the inner layer of the periosteum. They are characterized radiologically by a "saucer shape" appearance (Figure 6) and histologically, they are mainly chondroblastic. The periosteal OS is the intermediate grade and the HGSO is high grade counterpart. Future studies will define the relationship between these two entities.

Thus, we have excluded from the group of HGSO, tumors that are originating from the outer layer which are actually DPOS. Discriminative features of these two tumors are mainly radiological. In litigious cases, the study of MDM2/CDK4 amplification can be helpful.

Anyway, the discrimination between DPOS and HGSO is not clinically relevant since the treatment and the prognosis are the same.

Based on the origin of the tumor, we can propose a classification

Table 1: Reclassification of surface osteosarcomas according to their origin.

		Origin			
		Inner layer	**Outer layer**		
Grade of malignancy	Low or intermediate	**PerOS**	**cPOS**	Wide resection	**Treatment**
	High	**HGSO**	**DPOS**	Wide resection + Adj CT	
		Saucer shape Located under the periosteum	Melon shape radiolucent line MDM2/ CDK4 +		
		Distinctive features			

of surface OS as shown in Table 1.

References

1. Kumar VS, Barwar N, Khan SA. Surface osteosarcomas: Diagnosis, treatment and outcome. Indian J Orthop. 2014;48(3):255-61.
2. WHO Classification of Tumors Editorial Board. WHO Classification of Tumors of Soft Tissue and Bone, 5th ed. Lyon, France: IARC Press; 2020.
3. Sbaraglia M, Bellan E, Tos APD. The 2020 WHO classification of soft tissue tumours: News and perspectives. Pathologica. 2021;113(2):70-84.
4. Nouri H, Maitigue MB, Abid L, Nouri N, Abdelkader A, Bouaziz M, et al. Surface osteosarcoma: Clinical features and therapeutic implications. J Bone Oncol. 2015;4(4):115-23.
5. Nahian A, Chauhan PR. Histology, periosteum and endosteum. In: StatPearls [Internet]. Treasure Island (FL): 2021.
6. Hang JF, Chen PCH. Parosteal osteosarcoma. Arch Pathol Lab Med. 2014;138(5):694-9.
7. Babinet A, Tomeno B, Forest M. Ostéosarcome de basse malignité. EMC, Appareil Locomoteur. Elsevier Paris; 2001.
8. Li N, Li L, Tegola LL, Ding Y, Liu W, Niu X, et al. Parosteal osteosarcoma with focal fatty metaplasia: A case report. Radiol Case Rep. 2019;14(2):200-3.
9. Bertoni F, Bacchini P, Staals EL, Davidovitz P. Dedifferentiated parosteal osteosarcoma: the experience of the Rizzoli Institute. Cancer. 2005;103(11):2373-82.
10. Sadiq M, Ismail M, Dhanya K, Meganath P. Parosteal osteosarcoma of the proximal phalanx of a finger. J Hand Surg Am. 2020;45(7):663.e1-7.
11. Kumm DA, Rütt J, Hackenbroch MH. Parosteal osteosarcoma of the tarsus. Arch Orthop Trauma Surg. 1997;116(6 7):437-9.
12. Harper K, Sathiadoss P, Saifuddin A, Sheikh A. A review of imaging of surface sarcomas of bone. Skeletal Radiol. 2021;50(1):9-28.
13. Laitinen M, Parry M, Albergo JI, Jeys L, Abudu A, Carter S, et al. The prognostic and therapeutic factors which influence the oncological outcome of parosteal osteosarcoma. Bone Joint J. 2015;97-B(12):1698-703.
14. Gamberi G, Ragazzini P, Benassi M, Ferrari C, Sollazzo M, Molendini L, et al. Analysis of 12q13-15 genes in parosteal osteosarcoma. Clin Orthop Relat Res. 2000;377:195-204.
15. Martin JW, Squire JA, Zielenska M. The genetics of osteosarcoma. Sarcoma. 2012;2012:627254.
16. Papathanassiou ZG, Alberghini M, Thiesse P, Gambarotti M, Bianchi G, Tranfaglia C, et al. Parosteal osteosarcoma mimicking osteochondroma: A radio-histologic approach on two cases. Clin Sarcoma Res. 2011;1(1):2.
17. Yoshida A, Ushiku T, Motoi T, Shibata T, Beppu Y, Fukayama M, et al. Immunohistochemical analysis of MDM2 and CDK4 distinguishes low-grade osteosarcoma from benign mimics. Mod Pathol. 2010;23(9):1279-88.
18. Jelinek JS, Murphey MD, Kransdorf MJ, Shmookler BM, Malawer MM, Hur RC. Parosteal osteosarcoma: Value of MR imaging and CT in the prediction of histologic grade. Radiology. 1996;201(3):837-42.
19. Okada K, Unni KK, Swee RG, Sim FH. High grade surface osteosarcoma: A clinicopathologic study of 46 cases. Cancer. 1999;85(5):1044-54.
20. Sheth DS, Yasko AW, Raymond AK, Ayala AG, Carrasco CH, Benjamin RS, et al. Conventional and dedifferentiated parosteal osteosarcoma. Diagnosis, treatment, and outcome. Cancer. 1996;78(10):2136-45.
21. Miyashita H, Yoshida K, Soma T, Kameyama K, Sasaki A, Hisaoka M, et al. Dedifferentiated parosteal osteosarcoma of the maxilla: A case report and review of the literature. J Med Case Rep. 2018;12(1):235.
22. Cesari M, Alberghini M, Vanel D, Palmerini E, Staals EL, Longhi A, et al. Periosteal osteosarcoma: A single-institution experience. Cancer. 2011;117(8):1731-5.
23. Rose PS, Dickey ID, Wenger DE, Unni KK, Sim FH. Periosteal osteosarcoma: Long-term outcome and risk of late recurrence. Clin Orthop Relat Res. 2006;453:314-7.
24. Unni KK, Dahlin DC, Beabout JW. Periosteal osteogenic sarcoma. Cancer. 1976;37(5):2476-85.
25. Lichtenstein L. Tumors of periosteal origin. Cancer. 1955;8(5):1060-9.
26. Gulia A, Puri A, Pruthi M, Desai S. Oncological and functional outcome of periosteal osteosarcoma. Indian J Orthop. 2014;48(3):279-84.
27. Chan CM, Lindsay AD, Spiguel ARV, Gibbs CP, Scarborough MT. Periosteal osteosarcoma: A single-institutional study of factors related to oncologic outcomes. Sarcoma. 2018;2018:8631237.
28. Liu XW, Zi Y, Xiang LB, Han TY. Periosteal osteosarcoma: A review of clinical evidence. Int J Clin Exp Med. 2015;8(1):37-44.
29. Yarmish G, Klein MJ, Landa J, Lefkowitz RA, Hwang S. Imaging characteristics of primary osteosarcoma: Nonconventional subtypes. RadioGraphics. 2010;30(6):1653-72.
30. Wadhwa N. Osteosarcoma: Diagnostic dilemmas in histopathology and prognostic factors. Indian J Orthop. 2014;48(3):247-54.
31. Bertoni F, Boriani S, Laus M, Campanacci M. Periosteal chondrosarcoma and periosteal osteosarcoma. Two distinct entities. J Bone Joint Surg Br. 1982;64(3):370-6.
32. Inwards CY, Wenger D. High-grade surface osteosarcoma. In: Santini-Araujo E, Kalil RK, Bertoni F, Park YK, editors. Tumors and tumor-like lesions of bone: For surgical pathologists, orthopedic surgeons and radiologists. London: Springer; 2015. p. 235-40.
33. Francis KC, Hutter RVP, Coley BL. Treatment of osteogenic sarcoma. In: GT Pack, IM Ariel, editors. Treatment of cancer and allied diseases. Vol. 8, 2nd Ed. New York: Harper & Row; 1964. p. 374-99.
34. Wold LE, Unni KK, Beabout JW, Pritchard DJ. High-grade surface osteosarcomas. Am J Surg Pathol. 1984;8(3):181-6.
35. Okada K, Kubota H, Ebina T, Kobayashi T, Abe E, Sato K. High-grade surface osteosarcoma of the humerus. Skeletal Radiol. 1995;24(7):531-4.
36. Deng Z, Huang Z, Ding Y, Su Y, Chan CM, Niu X. High-grade surface osteosarcoma: Clinical features and oncologic outcome. J Bone Oncol. 2020;23:100288.
37. Staals EL, Bacchini P, Bertoni F. High-grade surface osteosarcoma: A review of 25 cases from the Rizzoli Institute. Cancer. 2008;112(7):1592-9.
38. Cutilli T, Scarsella S, Fabio DD, Oliva A, Cargini P. High-grade chondroblastic and fibroblastic osteosarcoma of the upper jaw. Ann Maxillofac Surg. 2011;1(2):176-80.
39. Lamplot JD, Denduluri S, Qin J, Li R, Liu X, Zhang H, et al. The current and future therapies for human osteosarcoma. Curr Cancer Ther Rev. 2013;9(1):55-77.