Chapter 9
Imaging-Based Indications for Resection with Epiphyseal Preservation

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Abstract The findings of imaging methods can be used to select cases in which we can try to preserve the epiphysis during tumor resection. In the 1980s, we were more cautious; with time and experience we have enlarged the indications for the technique.

Keywords Epiphyseal distraction • Limb salvage • Bone sarcomas • Growth plate • Epiphysis preservation • Indications • Imaging methods

9.1 Introduction

On the basis of the findings of the various imaging methods considered in Chap. 7, we can identify cases in which the tumor does not involve the epiphysis and in these cases adopt an approach to tumor resection which attempts to preserve the epiphysis. Such an approach involves a carefully coordinated chemotherapy program before resection, with the aim of minimizing the risk of local recurrence.

We carried out a study comparing several imaging methods that are employed in the evaluation of physeal involvement in primary malignant bone tumors. By correlating our findings with the histological features of each case, we were able to establish indications for our technique of epiphyseal preservation through physeal distraction (epiphysiolysis) before excision of metaphyseal bone tumors in children [1].

In our imaging study (Chap. 7), there were more false positive than false negative results; in the CT and MRI studies, there were no false negatives which confirms that MRI and CT scan are safe and reliable diagnostic techniques that allow us to

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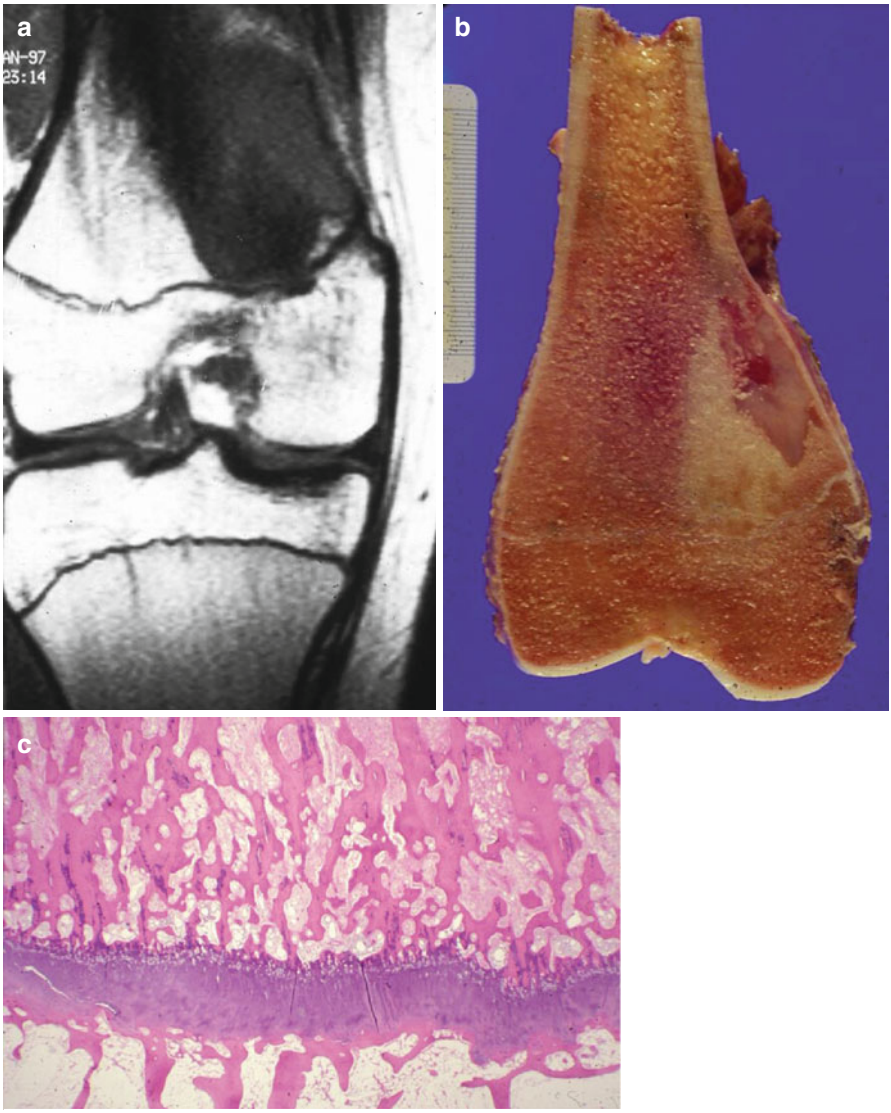

Fig. 9.1 (**a**) Osteosarcoma in the distal metaphysis of the femur of a 15-year-old boy. The tumor seems to have crossed the physis in the MRI image. (**b**, **c**) However, the histological study found no tumor cells in the physis

predict the location and extent of a tumor and, where oncologically appropriate, reduce the amount of bone resected [3–14]. The problem of false positives with CT and MRI (Fig. 9.1), however, could lead us to a sub-optimal treatment of certain tumors in terms of limb function preservation.

9.2 Stages of Invasion of the Epiphysis

Several years ago, in our department, we carried out a retrospective histological study of a series of malignant bone tumors in children [2] (*see* Chap. 6). The proportion of cases in which the tumor infringed the physis, about 50 %, was similar to that found with our subsequent study of imaging methods (*see* Chap. 7). In the histological study, we found that morphological lesions at the physis could be categorized into three types:

- The growth plate was not in contact with tumoral tissue.
- Areas of the growth plate were in contact with tumor tissue but were not penetrated by the tumor. Voluminous capillary sinusoids had introduced themselves between the columns of the matrix of the cartilage. The remainder of the physis appeared to be free of alterations.
- The physis was clearly invaded by the tumor. The areas crossed by tumor were surrounded by zones of thinned cartilage, similar to what was observed in the second type of lesion.

The implication of these observations is that invasion of the epiphysis by the tumor progresses in a predictable manner: first there is a hypervascularization reaction which leads to an early ossification of the growth plate, and after that the tumor crosses the physis.

9.3 Surgical Treatments

The surgical treatment we recommend for these tumors depends on the stage of invasion of the epiphysis as revealed by MRI. The three possibilities are presented below.

1. *The tumor has crossed the physis*.
   In such cases, preservation of the epiphysis is not possible (Fig. 9.2).
2. *The tumor is in contact with the physis*.
   There are three scenarios:

   - If all of the physis is affected (Fig. 9.3), the probability that tumor cells have crossed over the physis is high (*see* Chap. 5). However, most Ewing sarcomas and many osteosarcomas respond well to neoadjuvant chemotherapy, and if this response is particularly strong, preservation of the epiphysis should not be ruled out.
   - If the tumor is only in contact with part of the growth plate, tumor cells are less likely to have crossed over the physis and consequently we can try to preserve the epiphysis. After resection, external fixation can be maintained until intraoperative histological studies determine whether tumor cells are present in the physeal margin of the resection (Fig. 9.4). Then, on the basis of

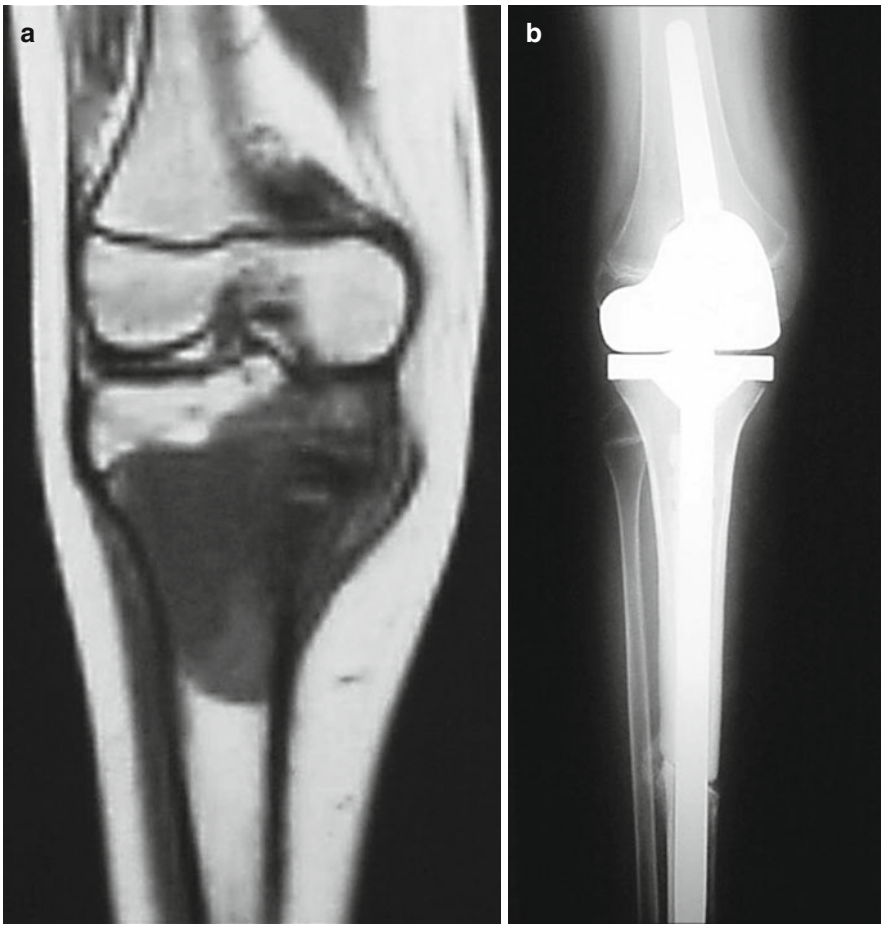

Fig. 9.2 (**a**) The growth plate has been crossed by this osteosarcoma in the proximal metaphysis of the tibia. (**b**) Reconstruction with a composite allograft-prosthesis

the histology, the appropriate manner in which to complete the surgical treatment (*see* Chap. 10) can decided. Before the advent of MRI, due to the lower accuracy of the other imaging methods employed, we used this methodology more frequently.

- An alternative method for preserving the epiphysis in cases when a tumor is in contact with only a part of the physis but does not cross it is intra-epiphyseal osteotomy, which may be useful especially in certain cases in children who are nearing the end of growth.

3. *The tumor is near to but not in contact with the physis*.
   Physeal distraction before excision is, in our experience, the best technique in such cases (Fig. 9.5). The safety of physeal distraction and the fact that it can preserve the whole epiphysis and most of the growth plate make it superior to other techniques such as epiphyseal osteotomy.

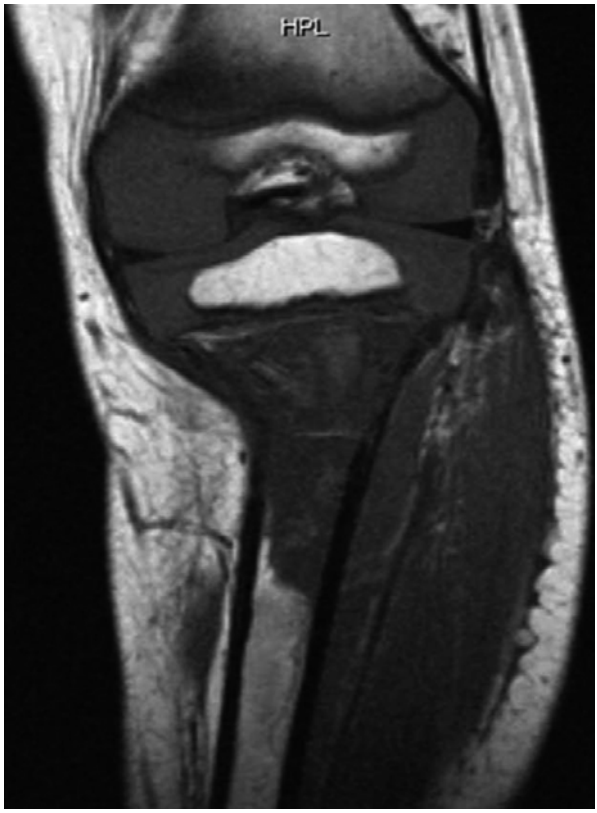

Fig. 9.3 Osteosarcoma in contact with the whole of the physis

9.4 Other Considerations

The fact that there are no anastomoses between epiphyseal and metaphyseal vessels, the possibility of using imaging methods to determine whether or not the tumor has involved the epiphysis, and the Cañadell technique for resection through physeal distraction [1, 11] together make it feasible, in selected cases, to preserve the epiphysis and the joint during tumor resection.

Physeal distraction is used in tumors of the distal femur, proximal tibia, proximal humerus, distal radius, distal tibia, and distal fibula. In locations such as the proximal fibula or proximal femur, physeal distraction is not used for obvious reasons (Fig. 9.6). In tumors involving the proximal metaphysis of the humerus, the particular morphology of the growth plate makes it possible to employ physeal distraction (Fig. 9.7).

The presence of a pathological fracture (Fig. 9.8) contraindicates physeal distraction because the distraction will occur through the fracture instead of through the growth plate. In such cases, intra-epiphyseal osteotomy could be used to conserve the epiphysis. However, if a fracture heals during the period of neo-adjuvant chemotherapy, it is still possible to perform physeal distraction (Fig. 9.9).

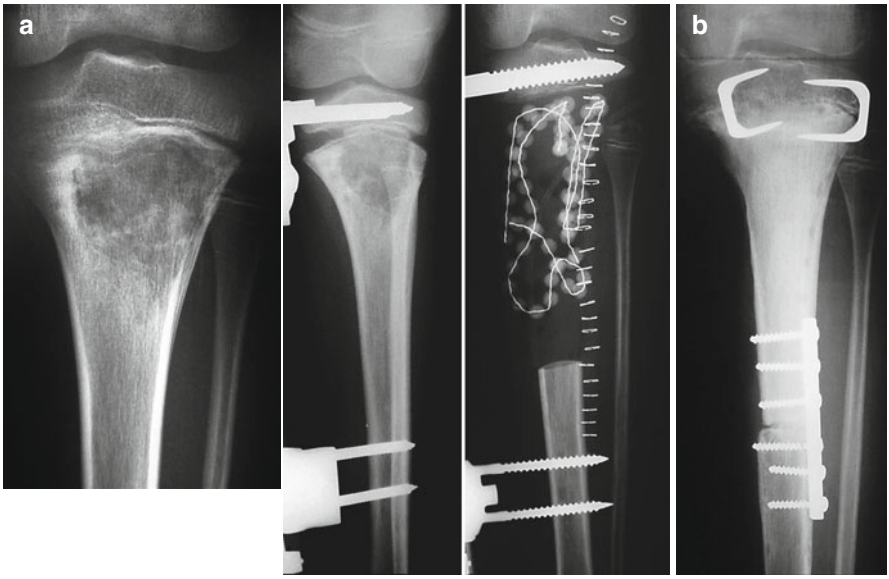

Fig. 9.4 Physeal distraction according to Cañadell's technique in a case in which involvement of the physis was uncertain, before the MRI era. (**a**) External fixation was kept in place after resection until histological study of the resection margins had been carried out. (**b**) After histological confirmation of the absence of tumor cells in the metaphyseal margin of the resection, the reconstruction was carried out with an intercalary allograft

Finally, note that physeal distraction serves no purpose in cases of diaphyseal tumors with a safe margin between the tumor and the physis [5] (Fig. 9.10).

Figure 9.11 provides a summary of the MRI-based indications and contraindications for tumor resection with physeal distraction in order to preserve the epiphysis. Of the patients we have operated on in accordance with the prescriptions of the Cañadell technique, none have suffered a local recurrence of the tumor in the retained epiphysis.

Fig. 9.5 (**a**) Osteosarcoma in the distal femur. The tumor is not in contact with the growth plate. There are some areas of edema between the tumor and the physis. (**b**, **c**) Physeal distraction was performed. (**d**) Reconstruction was by intercalary allograft. (**e**) Macroscopic appearance

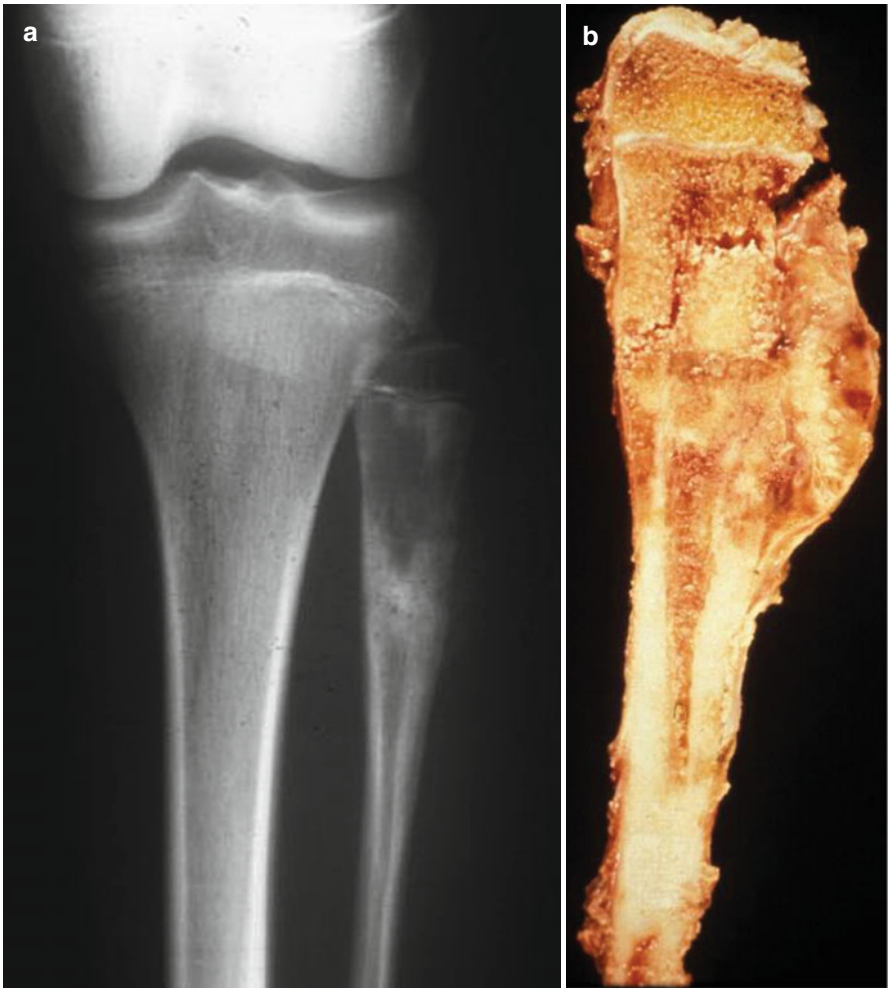

Fig. 9.6 X-Ray (**a**) and macroscopic view (**b**) of an osteosarcoma in the proximal metaphysis of the fibula of a 15-year-old girl. In such cases, it would not be appropriate to attempt to use physeal distraction and to preserve the epiphysis because of the risk of lesion to the peroneal nerve when placing the pins. Aside from this consideration, in this patient, the loss of the epiphysis does not imply any impairment in knee function

Fig. 9.7 The particular morphology of the growth plate of the proximal humerus allows placement of pins for physeal distraction

Fig. 9.8 (**a**) Pathological fracture in the distal tibia of a 9-year-old boy with an osteosarcoma. (**b**) The tumor did not transgress the physis. (**c**) X-ray of the resected piece. (**d**) Reconstruction was done by osteoarticular allograft

Fig. 9.9 (**a**) Ewing's sarcoma in the distal femur of a 10-year-old boy. Note the osteolysis in the metaphysis and the Codman triangle in the middle shaft. (**b**) A few days after diagnosis, this patient suffered a pathological fracture which healed after a few weeks. (**c**) The external fixation was placed. (**d**) Note the varus and shortening due to the fracture. (**e**) Epiphysiolysis was successful. The tumor was resected and the limb was reconstructed. The allograft healed. (**f**) The resected piece; note a fine layer of growth plate tissue covering the distal margin of resection

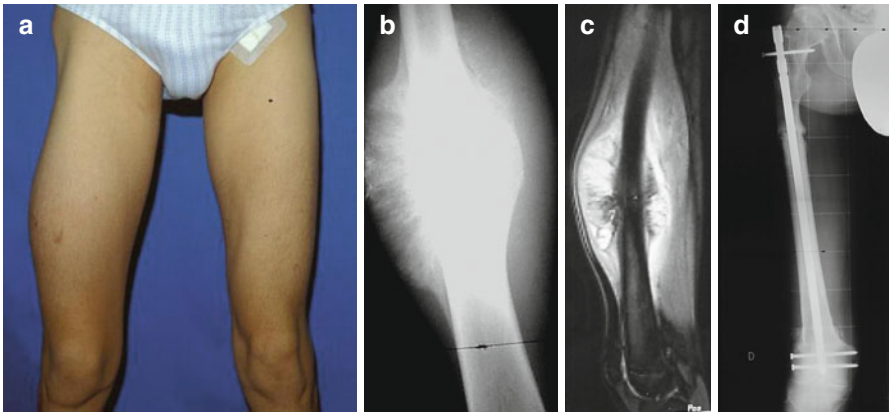

Fig. 9.10 Clinical picture (**a**) and X-ray (**b**) of an osteosarcoma in a 15-year-old boy. There was a safe margin between the tumor and the growth plate (**c**). The tumor was resected and reconstruction was carried out with an intercalary allograft (**d**)

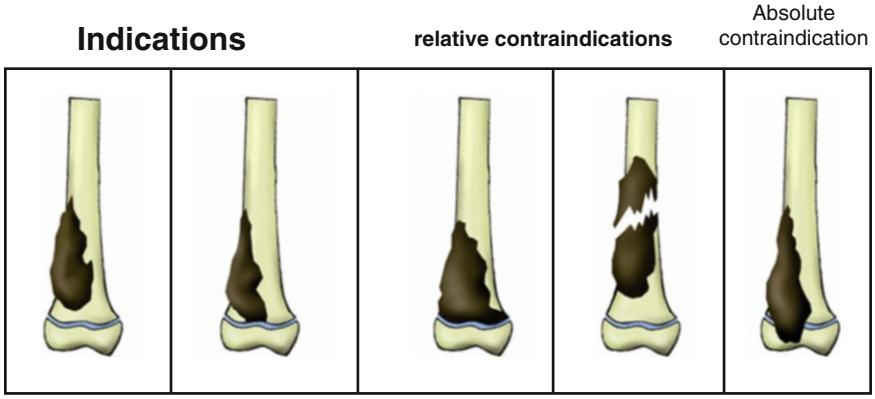

Fig. 9.11 MRI-based indications and contraindications for physeal distraction before resection of metaphyseal tumors

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