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Patient's selection and evaluation for bone stabilization

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Conflict of Interest

The authors have nothing to declare

Key Words

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ABSTRACT

Bone stabilization procedures performed by Interventional Radiologists have significantly increased in the past ten years with a wide variety of techniques available ranging from cementoplasty to complex combined treatment associating thermoablation, cementoplasty and fixation. Many available manuscripts and reviews focus on the technical aspects, feasibility and outcomes of these procedures. However, not every procedure is suitable for every patient, and therefore selecting a patient for a specific procedure represents the first necessary step to a successful procedure. This review will describe every step of the selection process which the Interventional Radiologists is confronted with prior to performing a consolidation procedure in the setting of bone cancer. Defining the clinical setting is mandatory and includes assessing the patient's clinical status, cancer stage, level of pain and disability will help define the objective of the procedure : curative, palliative intent. A thorough imaging assessment is also mandatory, as it will define the type of consolidation (cementoplasty or fixation) which will be performed depending on the anatomical location and size of the lesion, the type of stresses at stake (compression or shear) and it will help plan the needle pathway and assess for possible complications. The process of selecting a patient for a specific procedure should be performed by the Interventional Radiologist but should be validated in a multidisciplinary approach. Moreover, the objective of a procedure, including the expected outcome and possible adverse events and complications should clearly be explained to the patient.

Introduction

Bone stabilization procedures performed by Interventional Radiologists have significantly increased in the past ten years [1] [2] [3]. This increase in the number of interventions in bone cancer lesions might be explained by a combination of two phenomena's:

First, the high frequency of bone cancer [4] which is the third most frequent reported cancer) associated with the recent advances in cancer management, and a prolonged survival, explain the increase of the prevalence of bone metastasis over the past years [5].

Second, the tremendous progress of intervention radiology in the field of bone cancer management. Indeed, since the first vertebroplasty was performed in the early 1980's, IR has been experiencing incredible growth in the variety of procedures than can be performed, ranging from cementoplasty to tumor destruction and more recently bone stabilization through percutaneous screw fixation, and in some cases, complex combinations [6-10]. This is explained by several factors, including the mini invasiveness of both the procedures, sometimes performed under local anesthesia [11, 12] and of the devices used in IR. Moreover constant improvement of the imaging guidance combined to structural and organizational changes of Interventional Radiology, allows to offer in specific cases the *better, safer, faster,* and *less expensive* treatment options [13, 14]

In this setting, a number of studies have been published describing new techniques of bone stabilization, novel implants, and many reviews are available in this field. However, few papers focusing on patient's selection, and therefore indications of such or such techniques, are available to date.

The objective of this review is to detail when and why such or such bone stabilization technique can be offered, with special focus on patient's clinical setting, imaging evaluation, technical considerations and pre- procedure mandatory work-up.

Patient's selection process: the multidisciplinary phase

Because bone consolidation and stabilization techniques performed by IR are mini invasive procedures they can be offered to a wide array of patients, as opposed to surgical management. However, IR management of bone lesions should remain a patient tailored treatment and decision should be taken after a multidisciplinary discussion and a common consensus should be reached.

*Assessing the patient's setting and defining the objective of IR treatment

When assessing treatment options of a bone lesion, a major step is to define the oncologic setting of the patient, the type of metastasis, the stage of the cancer and the types of treatment, which will help define the objectives of the offered IR treatment.

Curative intent

In the setting of oligometastatic disease, a curative intent through IR may be possible [15]. In these cases, the objective is not only to alleviate pain if present, or to treat or prevent a pathological fracture, but to definitively treat the bone metastasis with a thermal ablative techniques. In most of these cases, consolidation is performed after thermal ablation, in order to prevent secondary fracture (FIGURE 1). Therefore, focus is made on the curative goal, and more aggressive therapies may be offered as opposed to the palliative setting.

Palliative intent

In the palliative setting, the objective is usually either pain alleviation, functional disability improvement, or both [16]. Bone lesions are indeed prone to generate pain and functional impairment, which are, along with hypercalcemia, commonly referred to as skeletal related events (SRE).

- *Pain alleviation [11] [12], Figure 2:* There are usually two types of settings in which the goal is to alleviate pain caused by a cancer bone lesion: uncontrolled refractory pain despite high dosages of oral therapy and poorly tolerated analgesic therapy despite low dosages. These two cases result in the same objective: to offer IR treatment in order to improve pain, and to avoid dose related drug complication and adverse events, particularly secondary to opioid use.

- *Functional disability improvement [17] Figure 3:* In case of either intense pain or pathological fracture, functional disability may be very high in patients with bone cancer. Therefore, bone consolidation techniques are performed in order to improve disability, and autonomy, thereby improving the quality of life. As opposed to surgery, IR procedures offer very limited post procedural rehabilitation. Therefore, the main objective is to achieve rapid improvement of disability, with, quite often, spectacular results in the following days after procedure.

*Assessing the patient's status

One of the advantages of IR procedures relies in their mini-invasiveness and therefore post procedural rehabilitation periods are very limited with rapid benefits for the patients. Therefore, IR procedures may be offered to a wide array of patients, even patients with a limited life expectancy or altered performance status. However, it is crucial that every situation be assessed thoroughly with regard to the benefit/risk ratio. Indeed, Patients with a low life expectancy and a severe performance status should not be offered complex combined

procedures. Other situations when patients have limited autonomy due to overall status alteration, may not need a procedure to prevent a fracture, when in fact, they are already unable to stand. Finally, in some other cases, complex treatments may require heavy sedation or general anesthesia which may add to the overall risk of the pre-procedure, thereby contra indicating the treatment with regard to the poor performance status of the patient. However, the overall status of the patient should be assessed using adequate scales, the most commonly used are the Performance status assessment, Karnofsky performance status (KPS), and Eastern Cooperative Oncology Group (ECOG) scales [18]. Once the performance status and cancer staging have been assessed, specific algorithms have been edited to help the decision-making process in the setting metastasis [19]

*Pre-procedure clinical evaluation

All of the above described details must be evaluated through a clinical consultation performed by the IR himself, including a physical examination, pain and disability assessment. There are many scales to evaluate Pain [20] disability and quality of life [21] [22], the most common being the VAS score for pain [23] , our preference goes the Pain disability index score

*** Procedure planning: Interventional radiologists' brain storming phase**

This phase is crucial as it will determine the feasibility of a procedure depending on the type of lesion, the type of fracture, the location of the lesion, the needle pathways, and the anticipation of possible adverse event. The type of procedure and devices will also be chosen during this phase which is the responsibility of the interventionists.

*Pre-procedure Imaging evaluation

In order to evaluate the feasibility and type of procedure which will be offered to a patient, the IR will have to thoroughly assess the imaging data. In cases of bone lesions, CT, MRI or very frequently both may be needed to accurately assess the tumor and plan the procedure.

Indeed, depending on the type of lesions and their location, MRI or CT may not suffice alone, as it is well known that these modalities are complementary Figure 4. In some cases, fusion/hybrid imaging such as PET-CT may be necessary [24].

Finally, the delay between the imaging data, the imaging assessment and the procedure must be as reduced as possible, as the risk of evolution in between imaging assessment and IR procedure may be high, possibly leading to last minute changes in the initial chosen strategy Figure 5

*Defining the type of fracture

When dealing with fractures in the setting of bone cancer, it is important to classify the type of fracture in order adapt the best possible treatment.

Bone insufficiency fractures are defined by a weakened bone secondary to treatments in relation to the cancer, such as chemotherapy, steroid therapy or radiotherapy . These fracture generate pain and disability, and are usually prone to consolidation techniques but without combination of thermal ablative procedure Figure 6

Pathological fracture are fractures secondary to a weakened bone due to extensive tumor infiltration usually involving bone cortex. These fractures also generate pain and disability, and are usually prone to consolidation techniques sometimes in combination with thermal ablative procedure to treat underlying tumor Figure 7.

Impending fracture is defined by extensive tumor spreading with an increased risk of fracture which has not yet occurred. These fractures may or may not generate pain and disability. Consolidation techniques are performed in order to prevent the occurrence of a pathological fracture. Combination with thermal ablative procedures to treat underlying tumor may be proposed in specific cases. (Figure 8)

*Assessing the type of bone lesions and the fracture risk

In osteolytic bone lesions, bone resorption exceeds the rate of bone formation, whereas in osteoblastic lesions the opposite is true. In both cases, a fragile bone structure is produced. In some cases, a mixt lytic and sclerotic lesion is present. The treatment options will differ in cases of a lytic, sclerotic or mixt lesion. Indeed, in case of a lytic lesion, PMMA injection will most probably be discussed, with or without addition of fixation, depending on the tumor location (see below). However, in case of a pathological fracture secondary to a sclerotic lesion, PMMA injection may not be possible, and fixation alone may be discussed.

Finally, in order to assess the risk of occurrence of a pathological fracture, several scoring system exist and may be used:

Concerning the spine, the Spinal Instability Neoplastic Score (SINS) [25] is commonly used and has shown an excellent inter and intra-observer reliability [26]. However, the Kostuik classification [27] is very simple to use, and has our preference in our daily clinical practice.

Concerning the long bones, two classifications exist and may be used : the MIrel's Score [28]and the Harrington classification [29]. Here again, because the MIrel's score is very easy to use, it has our preference

*Which lesion should be treated figure

In some cases patient present multi metastatic disease making it difficult to relate the pain to one metastasis or bone lesion. In these case, the outcome of the procedure is very difficult to predict, and if undergoing a procedure may present complications risks, the benefit of the procedure needs to be evaluated with regard to treating the pain generator. We are therefore accustomed to performing tumor block infiltration prior to consolidation or thermal ablation techniques in case of multiple metastasis in the area of the patient's pain. We strongly recommend doing so in case of multiple metastatic disease in order to avoid negative pain outcome secondary to a mistreated lesion (Figure 9)

*Technical considerations

Lesion location

Because the skeleton is designed to support weight, depending on the location of the bone tumor, it will be mandatory to assess the biomechanical forces at stake. The first step is to differentiate a weight bearing bone from a non-weight bearing bone. In case of a weight bearing bone, it will be mandatory to define the type of stress applied to this specific location: compression or shear stress. Indeed, depending on the type of stress, simple cementoplasty may be sufficient in case of a compression fracture (Figures 1-4, 6), whereas combined cementoplasty and screw fixation may be required when facing a shear, torsion or bending forces area (Figures 5, 7-9) . It is commonly accepted that the knee, the acetabula and the spinal column are exposed to compression stresses. On the other hand, long bones, and the pelvic girdle are exposed to shear stresses [2, 10, 30]. However, with the advances of the techniques available in IR, and depending on the type of lesion, highly lytic, complex fracture, combined cementoplasty and fixation may also be performed in some anatomical location mainly exposed to compression forces, especially the acetabular, spinal and sacral regions (Figure 10).

Lesion accessibility

Prior to any IR procedure, it is mandatory to assess the needle pathway feasibility. That is to define the accessibility of a lesion. A classic example is the posterior wall of the vertebral body, which may not always be accessible, due the presence of the spinal canal. Therefore, the needle planning phase is of the utmost importance, as it will predict the feasibility and possible complications of the procedure.

Lesion morphology

As previously described, the type of bone lesion, lytic, sclerotic or mixt will also influence the type of consolidation technique performed. However, evaluation of other basic morphological characteristics are mandatory in order to plan a procedure. The size of the lesion, the type of the primitive tumor (i.e renal carcinoma have a high bleeding potential), but also, in case of the need of a fixation, evaluation of the presence of sufficient normal surrounding bone in order for the inserted screws to be firmly fixed is crucial (Figure 5)

Assessing the risk of adverse events and complications

This phase is also very important and takes into consideration all of the above described steps. Indeed, anticipating possible adverse events or complications will be made on the overall status of the patients, the location, size, type of the tumor, the needle pathway, the surrounding anatomy and the type of procedure performed and devices used Figure 11

Outcome prediction and Defining the objectives

Once all of these steps have been processed, it is mandatory that a clear information on the possible expected outcome be exposed to the patient. Pain, improvement, tumor destruction, functional disability improvement and complications risks should be clearly discussed with the patient, and a 'moral contract' should be made in order to defined what can and cannot be expected of a procedure in the setting of a specific patient.

Conclusion

Bone stabilization techniques have become widely performed procedure by Interventional Radiologists, and thanks to the improvement of the guiding techniques and of the devices used, more and more complex, combined procedures are offered to patients in the oncological setting. It is mandatory to evaluate the accurate procedure to the appropriate patient. Offering the best possible procedure to a patient in a specific setting is the responsibility of the Interventional Radiologists. The necessary steps to evaluate the appropriateness of a treatment relies on the assessment of the patient' setting, including status, oncologic stage, pain and functional disability along with a thorough imaging assessment, including the lesion location, type, size, and environment. These analyses must lead to planning a procedure with the best risk/benefit ratio, which should be explained in detail to the patient in a clinical consultation.

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Figures

Figure 1

Example of a 55 y/o patients with lung cancer presenting with a unique painful lytic L2 metastasis (A1 and 2). Although the stability of the vertebral body is not compromised, stabilization with vertebroplasty was decided, with an analgesic goal. However, due to an oligo metastatic state, it was decided to associated thermal ablation, and microwave ablation was performed (B1 and B2), prior to cement injection (B3 and B4), during the same procedure. The one month follow up MRI showed a necrotic area (C1 and C2) with curative margin with regard to the metastasis. A recent CT performed 4 years later showed both the absence of bone collapse, and no metastatic recurrence (D).

Figure 2

75 y.o female patient with a colon cancer presenting multiple bone metastasis and a T7 mixed metastasis with secondary pathological compression painful fracture (Images A). Vertebroplasty was decided and performed (Images B) , allowing for an immediate pain decrease, along with significant reduction of opioid use.

Figure 3

This is a 63 y.o patient presenting with a painful pathological acetabular fracture secondary to lung cancer metastasis. The patient presents severe functional impairment, as standing is not possible due to the fracture (Images A). Decision to perform acetabular fixation with cementoplasty and screw insertion was made and subsequent procedure was performed (Images B), allowing for immediate pain response and functional improvement, with assisted standing possible. Patient was discharge with physical rehabilitation. Unfortunately, one month later, the patient presented recurring pain while standing. A CT scan showed extension

of the fracture lines in the coronal and axial planes (arrows, images C). Further fixation was decided and performed under dual CT and fluoroscopy guidance (Images D and E). Complete pain decrease was immediately obtained the following day, persisting in the following months.

Figure 4

This is an example of an L3 lytic metastasis in a patient presenting with kidney cancer. The metastasis was discovered on a CT (Image A), performed in the setting of low back pain and right cruralgia. An MRI was performed to evaluate tumor extension in the canal, and to adapt the procedure. In this case, thermal ablation with microwave ablation (Images C) was performed under light sedation, along with vertebroplasty, in order to reduce the risk of epidural leakage. After procedure, the patient benefited from pain reduction, both low back pain and cruralgia.

Figure 5

Example of a 53 y.o patient presenting a metastatic breast cancer relapse, with multiple bone lytic lesions including this large iliac lytic metastasis (Images A) for which multidisciplinary decision consisted of a combination of a consolidation procedure followed by radiotherapy. Interventional radiologist had planned to perform a combined fixation and cementoplasty, as sufficient normal bone was present to allow correct screw on bone fixation, as depicted in images B (white circle). However, the delay between the CT used for procedure planning and the procedure itself was one month, with a progression of the lesion and extension to the posterior aspect of the iliac crest, as shown in images C (black circle) . In this situation, the fixation procedure was compromised, and management strategy was modified : radiotherapy was performed first, and fixation would be re discussed depending on the evolution.

Figure 6

This is an example of T8 and T9 bone insufficiency vertebral compression fracture occurring in the same patient as in figure 1, 5 years after L2 management. CT scan (Image A), T1 en T2 WI MRI images (Images B and C) are in favor of osteoporotic fractures, secondary to bone weakening in relation to the chemotherapy and repetitive steroid therapy in this patient. Simple vertebroplasty was performed (Image D).

Figure 7

Example of a pathological femoral neck fracture (Images A) secondary to a melanoma metastasis in a female patient. The patient presented a high level of pain and functional disability, for which a percutaneous fixation was decided. A combination of 3 three 6.5 mm screws were inserted along with cement injection (Image B). After a delay of 7 days, patient benefitted from pain decrease. Assisted standing was allowed for the following 6 weeks.

Figure 8 :

Example of a 55 y.o patient with a lung cancer and a unique progressing metastasis located on the iliac crest, despite radiotherapy (Images A) . A two step strategy was decided : cryotherapy with a curative intent was performed (Image B), MRI was performed at one month (Image C) showing safe margin and complete tumor destruction. Preventive stabilization with screw insertion and cement injection was performed in a second step, 3 months after cryoablation (Images D).

Figure 9

Patient with a multimetastatic lung cancer and a history of multiple upper thoracic vertebroplasties presents with recurring cervico-thoracic pain. level. The CT scan reveals multiple metastatic disease with several pain generators possible. However, because pain was present palpation, T1 posterior spinal process fracture was suspected of generating pain

(Images A). In order to confirm the origin of the pain, 2 injections were performed at 4 weeks interval, with, in each case, complete resolution for 3 weeks (Images B) . Fixation with cement and a 4.5mm screw insertion were performed (Images C, D, E) with the assurance of a positive outcome : complete and definite pain reduction was obtained after fixation.

Figure 10

Images on the left corresponds to anatomical areas historically divide into : compression forces in blue and shear forces in red. According to this description, when a lesion is situated in a blue area, treatment option is usually cementoplasty and in the red area fixation may be performed. However, evolution of the techniques and devices have created a 'purple' area, for which compression and shear forces may be present, and combination of fixation and cementoplasty may be performed.

Figure 11

This is an example of the needle planning phase in a combined thermal ablation and fixation of an ilio pubic metastasis of a kidney cancer in a 59 y.o patient. A possible adverse event is lesion to the inguinal canal (white circle) during the needle insertion. Therefore, planning the needle pathway (white lines) ahead of the procedure to evaluate the distance between the needle and the inguinal canal is important in this case (Images A). The procedure was performed under CBCT guidance (Image B) and the control CT showed satisfactory screw placement, with a safe distance between needle pathway and inguinal canal (Image C).





















