INTRODUCTION

Thanks to ongoing technological advances involving equipment and materials, interventional radiology is playing increasingly important diagnostic and therapeutic roles in various fields. In the field of orthopedic oncology in particular, computed tomography (CT)-guided biopsy procedures are being used more and more frequently to ensure pathological diagnoses with high specificity and sensitivity (Bibbo).

Therapeutic procedures such as cementoplasty, embolization, radiofrequency ablation, and other approaches that are less widely used are being employed with curative objectives as well as for simple palliative purposes (Bibbo; Gottfried, 2004). In the pages that follow, it will be analyzed and described various aspects of these procedures including techniques, materials, indications, and the most recent results reported in the literature.

CT-GUIDED BIOPSY

The use of modern radiological techniques like CT, magnetic resonance imaging (MRI), bone scintigraphy, and positron emission tomography-computed tomography (PET-CT) is leading to the identification of increasingly small bone lesions that are sometimes asymptomatic. Histological diagnosis of a bone lesion often changes the strategy that has been adopted for its management. Open-sky biopsies are still considered the gold standard, but percutaneous needle biopsy is now being performed in numerous centers thanks to its low cost, decreased invasiveness, and low-complication rate. This approach is based on fine-needle aspiration of material for cytological analysis and collection of material for histological studies (figure 99). Depending on the location and type of the neoplastic lesion and on the experience of the operator, these biopsies are performed under sonographic, radioscopic, or — in most cases — CT guidance (Gottfried, 2008). They are indicated for all types of bone lesions (radiolytic or radiodense) that require cytological and histological typing. Major bleeding diathesis is the only real contraindication. Percutaneous access and an unobstructed pathway to the lesion — far from anatomic structures that might be damaged by the needle — are indispensable prerequisites.

From a technical point of view, the CT-guided biopsy procedure begins with the application of a radiopaque localizer to the skin (over the lesion). Local anesthesia is then induced (down to the periosteal level), and the biopsy needle is inserted and advanced continuously under CT fluoroscopic guidance (if the scanner is equipped for this type of imaging). Otherwise, the needle can be advanced in a stepwise manner and its position checked with consecutive scans (Callstrom, 2002; Sabharwal). Last-generation biopsy needles have a special stylet that is inserted through the cutting sheath, after the latter has been advanced into the lesion, blocking the sample, thus eliminating the need for luxation maneuvers. This feature makes the biopsy less invasive and better tolerated by the patient. It facilitates maneuverability and allows more rapid collection of specimens that are almost always sufficient for diagnosis. Current reports in the
literature on percutaneous CT-guided needle biopsy show diagnostic accuracy ranging from 75 and 100 per cent with sensitivity of 90-93 per cent and specificity of 94-95 per cent. Percutaneous needle biopsy is rarely associated with complications. Even in large case series, the rates are below 0.5 per cent, and most of the complications occur during biopsy of the vertebrae (Callstrom, 2006). Hemorrhage, hematoma, pneumothorax, infection, and nerve-root lesions have all been described.

Percutaneous needle biopsy is the method of choice for histotyping bone lesions because of its low invasiveness, high-diagnostic accuracy, low-complication rate (compared with open-sky biopsy techniques), and reduced cost (related to the fact that the procedure can be performed in the day hospital).

CEMENTOPLASTY

Cementoplasty consists in the injection of a nonacrylic cement into a bone cavity for therapeutic and palliative purposes. The first application of this technique was the vertebroplasty procedure described in France by Galibert et al in 1987 for the treatment of vertebral angiomas. This was followed by kyphoplasty and bone cementoplasty. The latter technique is used mainly for the treatment of painful osteolytic bone metastases. It is performed under local anesthesia with CT or fluoroscopic guidance and involves placement of a special metal, beveled-tip needle within the lesion. Bone cement is then injected through this needle. This type of treatment is excellent for the management of pain, especially in load-bearing bones at risk for pathological fractures (pelvis, femur). In some cases, cementoplasty is preceded by radiofrequency thermal ablation to reduce the amount of neoplastic tissue. The therapeutic effects include cytodestruction, palliative pain control, and stabilization (Bibbo; Gottfried, 2008).

PERCUtaneous verteBroplastY

Percutaneous vertebroplasty involves injection of radiopaque bone cement into the body of a vertebra by means of a metal needle inserted under fluoroscopic or CT guidance. As noted above, this method was developed in the mid-1980s to treat vertebral angiomas. More recently it has been widely used in western countries to stabilize osteoporotic fractures.

Technique

All patients scheduled for percutaneous vertebroplasty should have a complete anesthesiological assessment with emphasis on pulmonary function. Ventilation may be compromised by the prone position assumed by the patient during the procedure and by the
toxic effects of the volatile component of the cement. Blood pressure, oxygen saturation, and electrocardiographic activity are continuously monitored for the duration of the procedure. In most cases, access is established under radioscopic guidance. The combined use of CT and fluoroscopy is indicated only for the treatment of cervical or upper dorsal vertebrae.

After premedication and the administration of a mild sedative, the bone entry site is identified, and local, deep periosteal anesthesia is induced with a Chiba needle (18 or 22 G, 10 cm in length). Vertebroplasty needles (which may be marked with a centimeter scale) vary in caliber (11-13 G) and length (10 to 15 cm). They have beveled tips and small lateral wings that facilitate rotation.

**Figure 100** - A-C) Vertebroplasty for the treatment of osteolytic metastases.
Posterior extension of the destructive process should be carefully evaluated if vertebroplasty is being considered (Mannion). In these cases, extra care is needed to prevent posterior leakage of the cement. The presence of intensive neovascularization with venous anastomoses facilitates introduction of the cement into the paravertebral venous plexi, which drain into the vena cava, and this can lead to pulmonary embolism. Pathological vascular networks can be examined before vertebroplasty with vertebrography performed with a water-soluble iodinated contrast agent. This substantially reduces the risk of pulmonary embolism, whereas the leakage of small amounts of cement into the paravertebral veins is not generally associated with clinical effects.

**Patient management**

Patients being considered for vertebroplasty should be subjected to a complete work-up that includes CT (to determine how much of the vertebral body has been destroyed) and MRI (to assess the edemigenic neoplastic soft tissue component). In addition to the anesthesiological assessment, an electrocardiogram and chest X-ray are also useful since the patient will be mildly sedated and subjected to neuroleptanalgesia during the procedure, and the prone position in which he or she must be placed can potentially compromise ventilation. Laboratory tests should also be performed to evaluate clotting times and detect any coagulation deficits (especially if the patient has undergone chemotherapy). As noted, the procedure is performed under local anesthesia. After the operation has been completed, the patient remains under close observation for several hours. Later, loading bearing is reintroduced. In most cases, no drug therapy is needed.

**Results**

Numerous clinical studies have assessed the efficacy of percutaneous vertebroplasty in patients with osteoporotic vertebral fractures. Fewer studies have focused on the use of this technique in patients with neoplastic vertebral disease. The studies that have been conducted have documented significant reductions in pain, within 24 hours after treatment of osteoporotic fractures and within 72 hours after treatment of neoplastic lesions, leading to decreased use of analgesic drugs and improved quality of life. In the treatment of neoplastic lesions, the mean success rate reported in the literature is over 80 per cent. The persistence of pain reported in 6 to 25 per cent of treated patients can be due to neoplastic involvement of the pedicle or paravertebral regions, where the cement rarely arrives, or by extension of the disease to the intraforaminal area (Albisinhi; Gottfried, 2008; Sabharwal).

**Adverse effects**

The only true adverse effect of vertebroplasty is collapse of the vertebra adjacent to the one(s) treated. Patients who undergo percutaneous vertebroplasty for neoplastic involvement generally have widespread osteoporosis secondary to cortisone treatment or chemotherapy, and when one or more vertebrae are consolidated and stabilized, the contiguous vertebrae are subjected to trauma. This risk should always be considered in the preoperative work-up.

**KYPHOPLASTY**

Kyphoplasty can be performed as a percutaneous procedure or as a surgical procedure under general anesthesia. It combines the techniques of vertebroplasty and angioplasty to restore the original height and angle of kyphosis of a fractured vertebra. Compared with vertebroplasty, kyphoplasty includes an intermediate phase after the needle has been inserted inside the vertebral body. A balloon catheter is introduced and inflated with contrast agent to repair the collapse and restore the original height of the vertebral body. The balloon is then deflated and removed, and cement is injected through the needle, filling the cavity created by the balloon and stabilizing the fracture (Callstrom, 2002; Sabharwal).
Physicochemical characteristics

The cement, which is the same type employed for vertebroplasty, is a low-viscosity polymer with a low-polymerization temperature composed of methyl acrylate in powder form, solvent (poly(methacrylate), and a radiopaque powder. There are polymers on the market today that resemble cortical bone and have a porous microscopically structured that facilitates permeation. During polymerization, the cement reaches a temperature of 55-65 °C for a period of less than 30 s, and this increases its cytotoxic effects. In fact, apart from its mechanical effect, the cement also has analgesic and antitumoral actions. The analgesic effect is due in part to the heat produced during polymerization, which causes neurolysis of the vertebral and periosteal nerve terminals. This effect is associated with chemical neurolysis caused by the nerve endings' contact with methyl acrylate. This contact and the heat that develops during polymerization are both short-lived, so it is more likely that the analgesic effect is related mainly to stabilization of the vertebral fracture, which improves spinal mobility. Nonetheless, involvement of the thermal and chemical effects of the cement cannot be excluded. Methyl methacrylate is highly cytotoxic before it undergoes polymerization, that is solidification, and it exerts powerful destructive effects on the tumor cells. This action explains why significant extravertebral spread of the tumor is not observed after kypho-vertebroplasty, and there is generally no invasion of structures outside the vertebral body since the neoplastic tissue therein is destroyed.

Indications and contraindications

These are the same as those for vertebroplasty. Although the issue is still controversial, kyphoplasty theoretically offers the advantage of restoration of the original height of the vertebral body, reducing its deformity, and improving spinal dynamics. In addition, creation of a cavity within the vertebral body facilitates low-pressure injection of the cement, reducing the risk of extravertebral leakage.

Results

The results are effectively similar to those produced by vertebroplasty in terms of the resolution of pain, but kyphoplasty is reportedly associated with more marked improvement of pathological curvature of the spine.

Adverse effects

Kyphoplasty not only consolidates the vertebral body, it also restores its original height, and this increases the risk of compression of adjacent vertebrae.

Patient management

In terms of patient management, kyphoplasty differs from vertebroplasty only when it is performed as a surgical procedure under general anesthesia. In these cases, the patient will require a preanesthesia work-up. As with vertebroplasty, the rapid resolution of pain that follows kyphoplasty allows early mobilization of the patient.

EMBOLIZATION

Indications

Hypervascularization is a typical characteristic of many malignant tumors, especially when they metastasize to the bone. This feature is a major obstacle to surgical resection since it carries the risk of massive hemorrhage. Preoperative transcatheter arterial embolization can reduce this risk significantly. This approach is also indicated for palliative treatment of bone metastases causing nerve compression or pain. The procedure is currently used on metastases originating from renal tumors, breast or thyroid cancer, bronchial tumors and melanomas. It is especially useful for metastatic lesions of the spine and pelvis (Bibbo; Gottfried, 2003, 2004, 2008; Heary; Sabharwal; Sun).

Patient management and technique

The patient should always undergo CT or MRI prior to embolization (figure 101). These
studies provide information on the exact location and dimensions of the lesion to be treated as well as on its vascularization (Gottfried, 2003, 2008). The procedure is performed in the angiography room. Access is gained through the most appropriate artery, in most cases the common femoral, and the angiographic catheter (4 or 5 F) is advanced until it is near the lesion (figures 102 and 103). The preoperative diagnostic angiographic study is of considerable importance because it reveals the vessels supplying the lesion, the characteristics of the newly-formed vessels, and any collateral vessels or arteriovenous shunts that may be present (figure 102). This information is very useful for planning the embolization. If a medium-caliber vessel is embolized, vascularization is likely to be restored via collateral circulation; however, the occlusion of small branches carries the risk of ischemic lesions (Gottfried, 2003).

The patient is hospitalized if surgical resection is going to be performed 24-48 h after the embolization procedure (Bibbo; Sabharwal). If the embolization is purely palliative, the patient can be monitored closely for the first few hours and discharged 24 h after the procedure (if all goes well).

**Physicochemical properties of the material used for embolization**

The material used for embolization depends on the desired extension and duration of the embolization. Embolization materials are

**Figure 101** - CT without contrast enhancement. Solid, expanding metastatic mass causing osteolysis of the left iliac wing.

**Figure 102** - Angiography of the left common femoral artery. Large neovascular plexus at the level of the left iliac wing supplied mainly by the left deep circumflex iliac artery. No evidence of arteriovenous shunting.

**Figure 103** - Angiography of the left common femoral artery after embolization. After superselective catheterization and embolization of the left deep circumflex iliac artery with PVA microspheres, the large neovascular plexus is no longer visible.