

Case Report

## The Carbon Fiber Intramedullary Nail in Pathological Humeral Shaft Fractures: Two Case Reports

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Received: 08-05-2015

Accepted: 09-09-2015

Published: 09-14-2015

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### Abstract

The preferred surgical treatment of pathological humeral shaft fractures is the intramedullary nailing. A carbon-fiber-reinforced polyether ether ketone (CFR-PEEK) radiolucent nail allows for a stable internal fixation and better visualization of the fracture or pathological site on X-ray plain films, on computed tomography scan or magnetic resonance imaging also even the nail is in place, and enables a better power of radiation therapy in cases in which is indicated. Authors describe two clinical cases of patients with pathological humeral shaft fractures treated with this device until three months follow-up and discuss about the advantages and disadvantages of this new material.

**Keywords:** Pathological Humeral Fractures; Invisible Nail; Carbon Fiber Intramedullary Nail; Bone metastases

### Background

Pathological humeral shaft fractures are about 1/4 of all pathological fractures [1]. Primary tumors of this long bone are rare [2] and usually pathological humeral shaft fracture occurs after metastasis or systemic diseases like Multiple Myeloma [3]. The tumors most likely to metastasize to bone are prostate (32%), breast (22%), kidney (16%), lung and thyroid [4].

The implication of pathological tissue, after metastasize or primary tumor, creates some lytic or sclerotic areas in the cortical and cancellous bone. Lytic lesions are the most dangerous because they predispose the weakened bone to have spontaneous or after a minor trauma fractures. The humeral diaphysis gives sign of tumor localization late, very often after fracture has occurred [5]. The presence of substantial arm or shoulder pain in the patient with a history of cancer indicates the possibility of bone metastases, for which common characteristics include pain at rest, at night and unresponsive to non-steroidal anti-inflammatory

drugs (NSAID) [6].

In present time the treatment of pathologic humeral fractures, particularly of the shaft region, is surgery: non-surgical management gives poor results [6]. In fact when a pathological humeral shaft fracture occur surgical treatment reduce pain, morbidity and obtain fracture stabilization immediately: ensure a recovery of function with full weight-bearing as soon as possible. [7]. The preferred method of fixation of such fractures is the use of an intramedullary nail, as it promotes each of the above indications in the shortest amount of time [8]. Many surgeons also prefer the pre-emptive use of a nail for stabilization of an impending pathological fracture, which can be predicted when 50% of cortical bone destruction has taken place [9]. Intramedullary nailing can be done either closed or open through an anterograde or retrograde approach.

In this paper the Authors describe two clinical cases of patients with pathological humeral shaft fractures, the first following a localization of multiple myeloma and the second following a prostatic cancer metastasis, who decided to treat with a radiolucent intramedullary nail. On the market there are few materials those allow to have radiolucent properties and develop intramedullary nails: one of these materials is represented by Carbon-Fiber-Reinforced Polyether Ether Ketone (CFR-PEEK). The advantages of using this material in the pathological fractures are the radiolucent property, and then follow the better fracture or tumor evolution, and the possibility of subsequent radiotherapy with best result [10]. The Authors describe their experience with the Carbofix Humeral Intramedullary Nail (Unimedical-Biomedical-Technologies) demonstrating the good clinical and radiographic results obtained for both described patients monitored on 3 months follow-up according to the Musculo-Skeletal Tumor Society (MSTS) scoring system [11] and Constant Scoring System (CSS) [12]. The MSTS scoring system evaluates the functional condition after tumor treatment and it is calculated with a numerical value from 0 to 5 for each of six categories: pain, upper limb function, emotional acceptance, hand positioning, dexterity and lifting ability in the upper extremity. The CSS evaluates pain (score from 0 to 15), daily activities (from 0 to 20) and shoulder range of motion (considering the elevation, the internal and external rotation and abduction).

## Case Reports

### First Case

A 53-year-old female patient presented at our hospital in October 2009 complaining of musculoskeletal pain: a micro-molecular multiple myeloma was diagnosed with stage III A according to the Salmon-Durie Staging System [13]; she was initially treated with chemotherapy and, in April 2010, underwent autologous stem cells transplantation conditioned with

melfalan. After a period of clinical remission, one year later a bone marrow aspirate showed extensive plasma cells infiltration that constituted 80-90% of all marrow cells and the presence of circulant plasma cells in peripheral blood at immunofluorescence: it represented the progression of disease toward plasma cells leukemia. At this stage in October 2012 it was performed the second autologous bone marrow transplantation.

In March 2013 it was started the research of a HLA-matched unrelated donor (MUD) while the disease was progressing and the patient started complaining of severe musculoskeletal pain. Three months later the patient underwent allogenic peripheral blood stem cell transplantation and a further chimerism analysis revealed a complete engraftment but, in March 2014, she showed an extramedullary relapse with involvement of left humerus and lower jaw.

She later complained of a worsening pain at left shoulder without history of significant trauma and plain radiographs revealed a pathologic fracture of proximal humeral shaft. Pre-operative radiographic evaluation revealed multiple lytic bone lesions throughout the skeleton. It was then planned the surgical reduction and fixation of humeral fracture using Carbofix radiolucent humeral intramedullary nail and in the same occasion it was performed a partial resection of lower jaw.

A preoperative antibiotic prophylaxis with two grams intravenous Cefazolin (short term prophylaxis) thirty minutes before surgery was made performed and the surgical procedure lasted 54 minutes: authors did not report any intraoperative complications.

The patient did not require any recovery room hospitalization and was sent immediately to the Hematologic Department and five-days post-operatively she was discharged at home.

The physiotherapeutic protocol required the assistance of an orthosis for 25 days, starting a passive upper limb mobilization already 15 days after surgery. Surgical wounds dressings were renewed every 4 days and the (points) suture was removed 15 days after surgery without skin complications like infection or dehiscence.

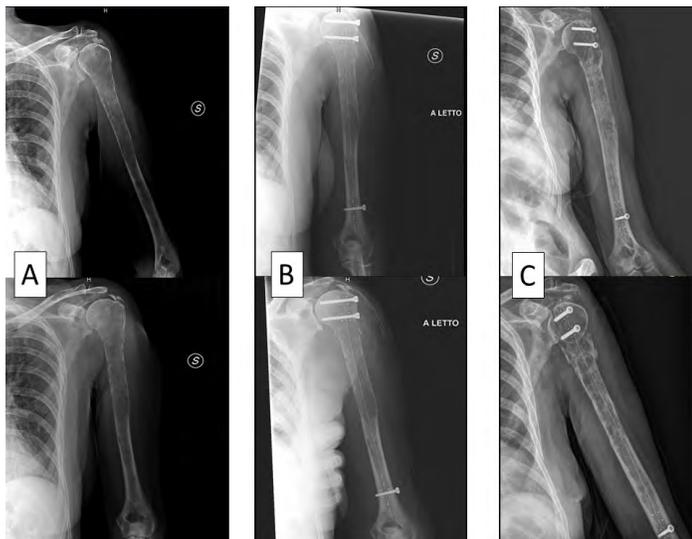
An antithrombotic prophylaxis was performed with Enoxaparin 4000 IU daily: authors did not found any deep vein thrombosis (DVT) complications.

At the first clinic follow-up (for removing the skin stitches) 2 weeks post-operatively the CSS was 45, and specifically she referred a complete pain remission already 5 days after surgery (during hospital dismissed). The following treatment program at the time would have included radiation therapy at left arm and jaw but the patient's condition was considered too critical to proceed. Furthermore it aroused an important and painful progression of disease with involvement of dorsolum-

bar spine that required new cycles of chemotherapy based on bendamustine with overall improvement of symptoms till nowadays.

At the first month follow-up control the patient had a score of 18 according to MSTS scoring system: a modest pain, an intermediate restriction in her upper extremity, satisfied emotionally, an intermediate position of her hand, a loss of fine movements and a limited lifting ability; at the third month follow-up control the MSTS scoring system was 28: no pain, a little restriction of her shoulder function with a range of motion in elevation of 160°, she was enthused, an intermediate hand position in the space, an intermediate dexterity with a limitation only when she did a fine work and a normal load about lifting ability. The CSS evaluations at one month and three months follow-up after surgery were 68 and 87, with a good improvement of function and no pain (Figure 1). At three-months follow up the radiographic evaluation showed a complete consolidation of fracture site (Figure 2).

**Figure 1.** M.L. 53-year-old female patient: clinical exam at 3 months follow-up.



**Figure 2:** Preoperative X-ray presentation of multiple myeloma humeral localization of the first patient [A], X-ray after Carbofix intramedullary nailing [B], X-ray three months after surgery [C].

## Second Case

A well-appearing 85-year-old male patient with past medical history of prostatic cancer and benign polyposis of colon presented at our hospital in January 2014 complaining of fatigue, lack of appetite, weight loss and persistent nausea. After complete investigations he was diagnosed with gastric adenocarcinoma and underwent total gastric resection; the following histological features demonstrated a pT4, N2 (5/23) cancer with tumor-free resection margins. Considered the patient's age and general condition, the oncologic team didn't subject him to chemotherapy.

After a period of overall well-being, the patient suffered a post-traumatic left humeral shaft fracture and was admitted to our department: radiographs didn't reveal any pathological involvement of fracture site and chest x-ray appeared normal. It was then planned the surgical reduction and fixation of fracture using the CarboFix radiolucent intramedullary nail and surgical specimens were collected and submitted to pathology for examination; a pre-operative antibiotic prophylaxis was made using two grams of intravenous cefazolin (short term prophylaxis) thirty minutes before surgery and the time of procedure was of 43 minutes. To prevent DVT complications, a prophylaxis with Enoxaparin 4000 UI daily was started immediately after surgery. Authors did not report any intra-operative complications; the patient did not require recovery room stay and was discharged home six days after surgery with the arm placed in a shoulder sling immobilizer.

The histopathology demonstrated the absence of malignant invasion of fracture site. The patient was seen in clinic five days post-operatively to monitor the surgical wounds and fifteen days post-operatively to remove the cutaneous sutures and to start the passive upper limb mobilization. No sign of skin complications were detected.

Also this patient was monitored on follow-up according to MSTS scoring system and CSS.

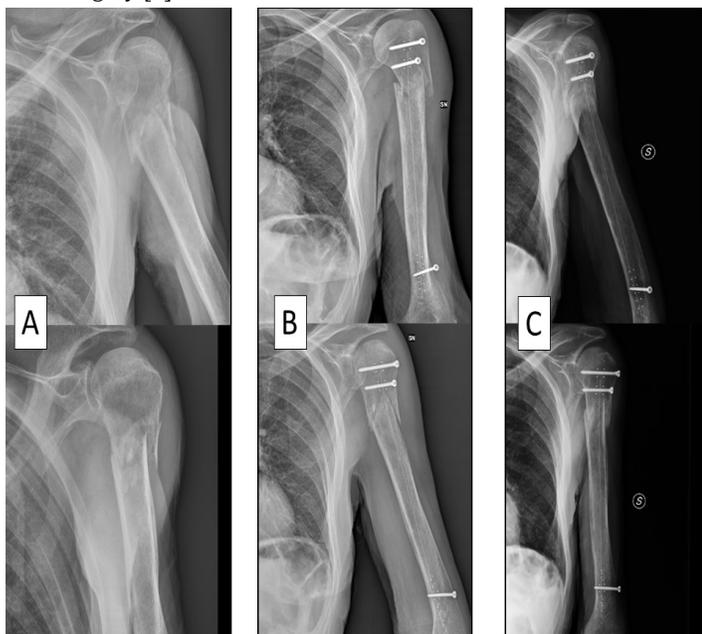
At the first month follow-up control the patient had a score of 14 according to MSTS scoring system: a moderate pain, an intermediate restriction in his upper extremity, satisfied emotionally, an intermediate position of his hand, a loss of fine movements and necessitating of help about lifting ability; at the third month follow-up control the MSTS scoring system was 21: no pain, the restriction of his shoulder function remained the same like the first month with a range of motion in elevation of 110°, he was enthused anyway, an intermediate hand position in the space and dexterity but a normal load about lifting ability. The CSS evaluations at one month and three months follow-up were 67 and 83, with a good improvement anyway of function and no pain (Figure 3).

At three-months follow up the radiographic evaluation showed a complete consolidation of fracture site also for this patient (Figure 4).

Figure 3: B.B. 85-year-old male patient: clinical exam at 3 months follow-up.



**Figure 4.** Preoperative X-ray presentation of pathological fracture without apparent tissue alteration signs of the second patient [A], X-ray after Carbofix intramedullary nailing [B], X-ray three months after surgery [C].



## Discussion

Pathological humeral fractures are about for 16–39% of all pathological fractures [1]: humeral localizations have a percentage approximately in multiple myeloma about 5.8% [3] and in prostate cancer about 7.3 [6]. Unfortunately in the pain exacerbates later, it has a sudden onset because it is often a manifestation of a fracture [5,13].

In these described clinical cases both patients presented a humeral shaft localization of disease. In literature the surgical recommended treatment options to reduce pain, primary goal for pathological fractures, are the intramedullary nailing and plating eventually reinforced with bone cement [4].

Even if an endomedullary nail is not very common in everyday orthopedic surgery we preferred to treat these patients with a closed reduction and nailing fixation technique because this allows for better results in the humeral district as already advised by some Authors [14]: reduce blood loss, surgical access, iatrogenic nerve lesion or skin problems associated with wound healing. Generally patients with bone tumor localizations have suboptimal clinical conditions and a large surgical access can heal late or generates complications such as infections or dehiscences. In our cases we encountered no similar complications, although an antibiotic prophylaxis (short and middle term) was made: small accesses are always recommended.

Another viable explanation why we chose an intramedullary nailing is because the upper limb pathologic fractures are often subjected to distractive forces inherent in lifting, pulling and heavy compressive forces, particularly in patients who require crutches or other devices to assist them in walking: thus an intramedullary nailing technique allows to control impaction, distraction, and torquing stresses with the use of proximal and distal interlocking screws [7]. Many Authors argue the major biomechanical advantages of intramedullary interlocking nailing compared to plating in pathological humeral shaft fractures. Damron et al [15] in an experimented with cadaveric models, Piccioli et al [16] in a retrospective study that evaluated different operative treatment options and related complications. The current literature have shown the actual validity of the nailing technique with radiopaque nails [7] but few Authors experienced the use of nail with radiolucent material [17]. A primary mechanical characteristic of the endomedullary nailing system is related to the construction materials: steel nails are stiffer and titanium ones have a modulus of elasticity closer to that of bone. Secondly, the ability to control the rotation forces is important: the rotation forces are generally controlled through the application of one or more transverse screws proximally and distally to the fracture. The possibility to lock both proximally than distally and link the fracture focus is feature that reduces significantly the nonunion risk [18]. Now-a-days CFR PEEK device allow it and a radiolucent property. This composite biomaterial provides the nail with biomechanical properties that mimic the elasticity of cortical bone, as well as allowing less strain and longer nail life in the patient than standard metal nails. Tests have shown the nail to be as strong as titanium nails and to have better fatigue properties [19].

A CFR-PEEK endomedullary nail permits a reduction of pain, with small accesses, and a better postoperative monitoring of fracture union through radiographic studies: the radiolucent property allows better visualization of the pathological site or the fracture on X-ray plain films, on Computed Tomography (CT) scan or Magnetic Resonance Imaging (MRI), after the nail is in place [17]. The surgeon can also follow the tumor pro-

gression or regression in cases of pathological fractures. The disadvantages of the CFR PEEK nails are the impossibility to pass over a guide wire, in fact these are uncannulated nails, and the placement of the distal interlocking screws: the distal screw holes are found with radiopaque markers.

Being this radiolucent nail the surgical technique is more complicated and surgical time is longer than other humeral nailing systems: this nail is uncannulated, then it is impossible to pass over a guide wire, and distal interlocking screws must be found with radiopaque markers. The surgical procedure using it must be carried out by expert hands, to limit the amount of ionizing radiation, especially at the beginning. The surgical procedure, in fact it is longer for the distal locking because the nail is radiolucent. It can be realized thanks to a performing "freehand": under fluoroscopy, the center of the distal end holes is located. Upon proper positioning, the two radiopaque markers (Figure 5) at each side of the hole should be aligned into a single line, thus appearing as a single dot at each side of the hole while the X-ray beam is parallel to the hole axis. An incision is made where holes are located and under fluoroscopy, and while nail markers at each side of a hole are aligned, (locate) the center of the hole is located with the 2.7 mm drill bit. It is then Selected the appropriate length of the 3.5mm diameter cortical bone screw, using the provided screw depth gauge. The screws are finally inserted through the interlocking hole in the nail, using the screwdriver.

**Figure 5.** The alignment of two radiopaque markers under fluoroscopy for distal locking.



Metastatic bone disease lead to a quality of life deterioration in cancer patients and a method that allows a quick pain relief

and restoration of a satisfactory function of the affected limb, in addition to a chance of healing of affected bone, is an opportunity not to waste. Although CFR-PEEK materials have already tested for synthesis devices in orthopedics [20] and traumatology [21] their development is still at the beginning especially with regard to the intramedullary nails in pathological fractures. The cost for this carbon fiber device is high, but we believe that this opportunity should be taken into account, especially in patients with an high prospect of life. Before surgical treatment both patients were in good health. In the first patient, with multiple myeloma, a bone marrow transplant had already been attempted, thus a big investment with a carbon fiber device can be justified for that patient's life. Even in the second case, although he was older, the prospect of life was higher than similar patients with the same type of cancer. Unfortunately the beginning of chemotherapy has not been possible for both clinical conditions.

Although authors are aware that this study is limited by the small number of people and a reduced follow-up they feel that this treatment is to experiment with expanding the casuistry and remote controls. So far the device showed a patient satisfaction, allowing reaching its goals: rapid functional recovery, immediate reduction of pain and good evolution towards the bone fracture healing. The display of the bone lesion during the follow-up period has enabled the specialists (orthopedic surgeons, oncologist and radiation oncologist) to monitor its evolution.

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