The role of amputation and bionic hand exoprosthesis in the long term treatment of renal cell carcinoma metastases to the upper limb

M. E. Pogarasteanu, M. Moga
“Dr. Carol Davila” Universitary Emergency Central Military Hospital, Bucharest, Romania
The Orthopaedics – Traumathology Clinic

Abstract

Renal cell carcinoma is a malignant tumor that metastasises to the bone. That being so, in Orthopedic practice it is a rare occurrence, but as with all metastatic tumors, it is important for the Urologist Surgeon to have a further understanding of the treatment possibilities for renal cell carcinoma bone metastasis to the upper limb. In order to get a clear view of this rare occurrence, we conducted a search on a database containing orthopedic articles (JBJS) and one on a large database that comprises medical and surgical articles (PubMed). This has shown that, although there are authors writing articles dealing with this pathology, there is not a great number of these articles. The surgical management of these cases, from an Orthopedic’s point of view, begins with a preliminary evaluation, and continues with biopsy, and resection. When resection is no longer an option, amputation is the surgical choice, and following that a prosthesis is fitted. There are modern surgical techniques and prosthesis models being developed in Romania.

Keywords: renal cell carcinoma, bone metastasis, upper limb

Correspondence to: Mark-Edward Pogarasteanu
Universitary Emergency Central Military Hospital
No. 88 Mircea Vulcanescu Street, Sector 1, Bucharest, Romania
Tel: +40213111311
E-mail: mark.pogarasteanu@gmail.com
Introduction

The aim of this article is to give a basic account of the diagnostic, treatment and postoperative options for a patient with upper limb bone metastasis following a renal cell carcinoma. Thus, we do not intend to give an account of the primary pathology, or of the area of treatment that falls under the sphere of Oncology considering that this is far out of our area of expertise, but only to achieve our aim, from an Orthopedic's point of view.

Renal cell carcinoma is a malignant tumor that can, and will metastasis to the bone. That being so, in Orthopedic practice it is a rare occurrence, rarely seen and treated, but as with all metastatic tumors, it is important for the primary care giver, in this case the Urologist Surgeon, to have a further understanding of the treatment possibilities for renal cell carcinoma bone metastasis to the upper limb, with an accent on the least desired surgical outcome (amputation) and the modern possibilities following that intervention.

Materials and methods

In order to get a clear view of this rare occurrence, we conducted a search on a database containing orthopedic articles (JBJS)(1) and one on a large database that comprises medical and surgical articles (PubMed)(2).

The search we conducted on JBJS (Journal of Bone and Joint Surgery) in June 2015, showed 96 articles, in all the combined categories, that dealt with renal cell carcinoma metastasis. Of these 96 results, we determine to be relevant those placed in specific categories: Shoulder (1 article), Hand & Wrist (4 articles), Spine (12 articles), Hip (5 articles), Knee (2 articles) and Foot & Ankle (4 articles). We also found and articles referring to a renal cell carcinoma metastasis to the radius in the Oncology category, that we found relevant to our inquiry.

The total number of results found were distributed over a large period of time, with 16 articles being published after 2009, and 17 articles being older than 1966. In total, 6 articles were found to be directly concerned with upper limb bone metastasis of the renal cell carcinoma, and 5 of these in the forearm and arm area.

Our search on PubMed for renal cell carcinoma metastasis found a total of 7406 articles, of which 2337 were published since 2007, and only 21 were published before 1966. A further search for renal cell carcinoma bone metastasis found 825 articles, of which 278 were related to the upper limb area, and of these, only 176 articles were concerned with the forearm and hand, as area of bone metastasis of renal cell carcinoma.

This shows that although there are authors writing articles dealing with this pathology, there is not a great number of these articles and, in the specialty journals at least, a large number of these articles are not recent.

Biopsy and resection

From an orthopedic point of view, renal cell carcinoma metastasis to the bones of the upper limb is a rare occurrence, with an outcome largely depending on the time at which the patient presents in the service.

The biopsy can be done after completing a full clinical and paraclinical examination, necessarily including imaging studies and an Oncology consult. If a renal cell carcinoma metastases is suspected from the beginning, an Urology consult must be made before any surgical act.

An extensive preoperative evaluation has several advantages in performing the biopsy:
- helps to precisely pin-point the site of the incision;
- helps in determining a precise and rapid diagnosis;
- lowers the incidence of therapeutical errors.

Due to the fact that the area in which the biopsy is performed may get contaminated with tumor cells, it’s placement must be decided with care, in order for it to permit a future excision together with the tumour, or even an excision in the context of an amputation.

Preoperatively, a haemosthetic band may be used, if the anatomical area allows so, but without draining the limb of blood through compression, because of the risk of mobilising tumour cells and of their migration. When dissecting to reach the tumor, it is desirable, if possible, to limit the plane of dissection to a single compartment, or better to a single muscle mass, in order to limit possible pathways for tumoral dissemination, a possibility in such cases.

Biopsy samples are taken, from either soft tumoral tissue, bone metastases, or both. If, in order to reach the bone metastases, the surgeon must open the cortical, the hole should have an ovoid or round shape, as any corner may be a point of potential fracture. Any such hole must be closed, either with the original cortical lid, or with bone cement, taking care as to not leave an access pathway for tumor dissemination, or any possibility for hematoma formation, as this could be contaminated with tumor cells (3). Also, a good practice is to deflate the tourniquet at this point and perform a careful hemostasis, before closing in anatomic layers.
The biopsy taken may be analyzed intraoperatively, by a pathologist present in the surgical theatre, in order to help in deciding the limits of safe resection, or it may be sent to a pathology laboratory for analysis.

There are several types of biopsy that may be performed:

- fine needle aspiration;
- core needle aspiration;
- open incision procedure.

Of these, the open incision procedure provides the greatest amount of tissue to be analysed, and has the fewest possible errors concerning site of biopsy and quality of tissue, but also has a larger rate of complications. Core needle biopsy and fine needle biopsy also have a high rate of providing a correct diagnosis, but have a lower precision, unless they are ultrasound guided, and provide much less tissue for analysis.

The next surgical stage in the treatment of metastases to the upper limb is the definitive procedure, and that may be performed only after the histological result confirms the clinical and radiographic diagnosis.

In those cases where the definitive procedure is to be delayed, or may not be possible at all, and there is a risk of fracture at the level of the tumoral bone, a prophylactic fixation may be performed in order to maintain the patient’s quality of life.

Usually, for a small tumoral mass, a primary resection (an excision biopsy) may be performed, withing safety margins, and those margins may be extended if necessary, in a future intervention.

For a larger mass, secondary resection may be performed, and if needed, the remaining bone area may have the defect grafted, or cemented. Another option that is often used is to replace the bone metastasis resection area with an internal prosthesis, usually for the joint area. Internal prosthetic replacements are available for non-articular areas too, but they must be custom-made, are expensive, and usually the time needed for their manufacturing would greatly postpone the time of intervention, giving the malignant lesion time to expand, and possible making the prosthesis redundant. If possible, a compartment resection is indicated, as it uses the natural limits of the compartment as a measure of precaution in the face of tumoral expansion.

The final stage procedure, and the one we are interested in taking a closer look at, is amputation of the afflicted segment, if all other removal procedures have been attempted without success in halting the tumor’s expansion, or if the tumoral mass is so large at the time of diagnosis that even compartment resection is out of the discussion.

**Amputation as treatment in upper limb metastases**

Thoracic limb amputation is considered as a final stage procedure, the last surgical mean of fighting a malignant pathology, impossible to control otherwise.

At the shoulder, an interscapulothoracic amputation consists in the surgical removal of the entire upper limb, using the interval between the scapula and the thoracic wall, as is usually indicated in the treatment of malignant tumors that can not be removed by a less extensive procedure. Often this procedure is extended to include the resection of a portion of the thoracic wall. The most often used approaches are the anterior, Berger, and the posterior, Littlewood, the latter being the faster and the easier to perform as a technique (3). Shoulder disarticulation consists in the surgical removal of the thoracic limb at the scapulohumeral joint, with the preservation of the glenoid and padding it with the periarticular musculature. The proximal transthumeral amputation is performed at the surgical neck of the humerus, thus preserving the scapulohumeral joint after closing the stump, which allows for some motion in the eventuality that a prosthesis is to be fitted; also, the esthetic results are far better in this procedure as compared to the procedures previously discussed.

At the level of the arm, the transthumeral amputation consists of the partial surgical removal of the throracic limb at any level: starting from the supracondylar area to the surgical humeral neck (the external reference is the axillary fold).

At the elbow the procedure recommended is the elbow disarticulation, and an amputation at this elvel has optimal functional results, as the width of the distal humeral epiphysis allows a stable fitting of the prosthesis, and the rotation can be preserved, being transmitted from the level of the humerus.

At the level of the forearm, the amputation can be performed at the proximal, medial, or distal third; it is important to remember that it is important to preserve as much healthy tissue as possible, in order to retain as much function as possible. If there is a circulatory problem, the level of amputation needs to be mid-level or proximal third, as the abundant musculature will sustain the healing process; distally, the skin is thinner, and the subcutaneous layer is not so well developed. Because functionally the preservation of the elbow
joint is crucial, whenever possible, a proximal forearm amputation is preferred, even if the remaining stump is extremely short, rather than an elbow disarticulation.

At the wrist, disarticulation or transcarpal amputation are to be desired as opposed to a forearm amputation, because thus pronation and supination may be preserved, and, in the case of the transcarpal amputation, even some flexion at the wrist is preserved.

At the level of the hand, there are a large number of amputation techniques, including partial amputation, one or several fingers, or ray amputation. The results depend on the technique that is used and on the patient’s capacity to adapt. Functionally, the most difficult for the patient is to adapt to the amputation of the thumb in the dominant hand, as the prehension function of the hand is lost.

**The conm amputation method**

Recently, a modified amputation technique has been developed in the SUUMC Hospital in Bucharest, Romania (4,5).

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The first stage is a thorough evaluation of the patient, medical and surgical. His needs are discussed and it is established whether he is a good candidate for this surgery and for the future fitting of a myoelectric prosthesis (Fig. 1).

If the decision is made for performing the intervention, the patient is prepared as for any upper limb major surgery, is anesthetized and a tourniquet is put around the arm and inflated (Fig. 2). An incision is made, and dissection is carried through to the level of the bone, whether it is a primary intervention or stump revision surgery. The muscles are isolated and prepared for transosseous suture, individually (Fig. 3). The bone is cut at a level shorter than that of the muscles, to create a padded end of the stump, and a set of holes is drilled in the bone (Fig. 4).

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**Fig. 1:** Amputated forearm in the OR Theatre, before revision surgery. Photo record from the Bucharest Central Military Hospital’s archive, Orthopaedics Clinic.

**Fig. 2:** Evaluation and planning in a forearm revision. Photo record from the Bucharest Central Military Hospital’s archive, Orthopaedics Clinic.

**Fig. 3:** The muscle groups are isolated and positioned for the CONM procedure in a forearm stump revision. Photo record from the Bucharest Central Military Hospital’s archive, Orthopaedics Clinic.

**Fig. 4:** The forearm bones are drilled in order to perform transosseous muscle anchorage for the CONM procedure in a forearm stump revision. Photo record from the Bucharest Central Military Hospital’s archive, Orthopaedics Clinic.
The individual muscle groups are sutured to the forearm bones, in order to prevent retraction later on, in a circumferential manner, modifying the natural arrangement of the forearm muscles into compartments, to a uniform layer of musculature, as this is believed to produce more myoelectric signals, since more of the muscles are close to the skin. Then, the remaining nerves are identified and transposed closer to the skin, the fascia is partially removed and the stump is closed with separate sutures.

Prosthesis options after amputation

Following an amputation, there is a period of healing of about 6 months, during which the amputation stump changes dimensions and characteristics, due to the processes of muscle atrophy and retraction. In this period the patient may use a temporary prosthesis, that is usually design and cheap, as it will be discarded once the stump has matured and a permanent, functional prosthesis may be fitted.

Prosthesis may be classified in either passive devices (worn primarily for aesthetic purposes), and active devices, that also incorporate a number of functions. These latter ones may be mechanical (body-powered), or electric.

Mechanical devices are operated and controlled using a harness and cable system that requires the patient to voluntarily open and close a terminal device, usually with a limited number of functions assigned to it; another possibility is for the patient to either open or close the device voluntarily, and the complementary action is performed automatically using an elastic band or spring type mechanism.

These mechanical prostheses provide the patient with an intrinsic feedback system, but it is rudimentary, in that the force exerted by the terminal device upon an object is transmitted to the patient’s amputated stump much in the same way one would feel the irregularities in a road through a bicycle’s frame.

Mechanical prosthesis have certain advantages: a lower acquisition and maintenance cost, less weight, they are easier to repair and they have an intrinsic feedback, but also have disadvantages: they have a more mechanical appearance, and they are harder to use for persons that lack in strength in the remainder of the limb.

Electric powered devices incorporate a battery to open and close the terminal device, and usually have a greater number of functions built into them. They are generally controlled by impulses from the musculature in the amputation stump, and are called myoelectric prosthesis, but this is not always the case, and there are even some in which the patient must push a button on the prosthesis with his other hand to open or close the device.

Electrical devices do not require cables and harnesses, and thus have a more natural look and feel, they do not rely on the patient’s own level of strength to operate them, but on batteries, and may be provided with a greater level of gripping force. Unfortunately, they also have a much higher cost, are heavier, easier to be damaged, and are dependant on the quality of the batteries.

Whether mechanical or electric, all prostheses are equipped with a terminal device. This may come in a number of fashions, but in all cases, the goal is to provide the patient with at least a small part of the hand’s basic function: to hold an object. There are three great categories of terminal devices: hooks (allowing the patient to grab an object, or to hold on to something), prehensors (claw-looking, they provide the key func-
tion of prehension, and mimic the basic design of the hand with it’s opposable thumb), and artificial hands.

In the modern age of prosthetics, although there exist very advanced robotic hands, the most practical solution that incorporates a high number of functions, a good control, and life-like appearance, at a moderately affordable price, is the myoelectric prosthesis equipped with a bionic hand as a terminal device.

Virtual reality assisted bionic hand prosthesis under development

Recently, research has been conducted by a team of engineers from the Bucharest Politechnical Institute that aims to develop a model for a locally-produced, economically viable model of prosthetic hand (6,7). The process includes the evaluation of each patient’s myoelectric signal strength, by placing EMG electrode receivers on the surface of the amputation stump (Fig. 6), and then recording the signal that is emitted by each individual muscle (Fig. 7, 8). This is done for each patient, both those that have underwent the classic procedure and those that have had the CONM surgery.

![Fig. 6: Hand amputation patient is prepared for preliminary testing of myoelectric signal strength using an EMG. Photo record from the Politechnic Institute in Bucharest.](image1)

![Fig. 7: Preliminary testing of myoelectric signal strength using an EMG. Photo record from the Politechnic Institute in Bucharest.](image2)

![Fig. 8: Distinct Adductor pollicis myoelectric signal record. Photo record from the Politechnic Institute in Bucharest.](image3)

After determining the exact number and position of the strongest signals, an experimental personalised prosthesis is constructed, and the patients train to use it with the help of a sistem that integrates a virtual reality experience (8). It is believed that in the near future this experimental prosthesis may be avalable to the public.

Conclusions

From an Orthopaedic point of view, the management of a renal cell carcinoma metastasis to the bones of the upper limb starts with a biopsy, and is followed by resection within safety margins. If this is not possible, the solution remains amputation, followed by the fitting of a prosthesis.

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