Application of Hip Amputation Under Non-Ischemic Condition in the Treatment of Sarcoma

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Technical innovations

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Abstract

**Background:** Amputation is an effective treatment for sarcoma of the hip. Traditional amputation is performed by separating the major arteries and veins of the limb and blocking the blood supply to the limb, which may have adverse effects on the patient.

**Methods:** Ten patients with pathologically clearly diagnosed bone and soft tissue sarcoma undergoing hip amputation in a non-ischemic state between April 2019 and April 2021 at the Affiliated Cancer Hospital of Harbin Medical University were selected. Factors related to operative time, intraoperative bleeding, phantom limb pain, incisional infection, and flap necrosis were statistically evaluated at 7 days postoperatively and 3 months postoperatively.

**Results:** Ten patients were followed up for 3-24 months with a mean of 13 months. No bleeding secondary surgical complications occurred in all patients, and none had postoperative infections. Postoperative flap necrosis occurred in one case in the modified hemipelvic amputation patients, and no flap necrosis occurred in the hip disarticulation patients. In the non-ischemic hemipelvic amputation group, the operation time was 4.5-5.5h, with a mean of 5h, and the operation bleeding volume was 300-1000ml, with a mean of 700ml; in the hip disarticulation group, the operation time was 2.5-3.5h, with a mean of 2.9h, and the operation bleeding volume was 300-450ml, with a mean of 357ml; phantom limb pain in the non-ischemic amputation group 7 days after operation, the VAS pain score was 4-6 points, mean 4.5 points; VAS pain score 3-4 points, mean 3.4 points at 3 months postoperatively.

**Conclusions:** In hip amputation for bone and soft tissue sarcoma, the main arterial and venous approaches to the limb are ligated near the end of surgery, leaving the amputated limb in a non-ischemic state at the distal end of the amputation, without pathological reactions due to limb ischemia. Non-ischemic hip amputation is more suitable for the surgical treatment of locally advanced lesions of sarcoma.

**Trial registration:** retrospectively registered

**Background:**

The femur and soft tissues of the thigh are the most frequent sites of bone and soft tissue sarcoma. For tumours with major vascular and nerve involvement and extensive invasion, a safe surgical border cannot be achieved by extensive local excision. Hip disarticulation and hemipelvic amputation continue to be important in the treatment of locally advanced sarcomas of the thigh. Traditional amputations usually begin with the dissection of the major arteries and veins of the limb, blocking the blood supply to the limb in order to reduce bleeding during the amputation procedure, which may have adverse effects on the patient due to the ischaemic state of the distal limb from the beginning to the end of the procedure. The effect of this surgical approach on bleeding, postoperative phantom limb pain and related complications was investigated by improving the surgical approach by ligating and severing the major arteries and veins of the limb near the end of the procedure, leaving the distal part of the amputated limb
Amputation is an effective treatment for bone and soft tissue sarcoma of the extremities. Traditional amputation usually begins with the separation of the main arteries and veins of the limb and is followed by ligation at the beginning of the operation to block the blood supply to the limb in order to reduce bleeding during the amputation, which may have adverse effects on the patient as the distal limb is ischemic from the beginning to the end of the operation. By improving the surgical method, the main arteries and veins of the limb are ligated near the end of the surgery and the distal limb is in a non-ischaemic state. In this study, we reviewed the data of patients diagnosed with bone or soft tissue sarcoma of the thigh, hip and underwent modified hemipelvic amputation or hip dissection at the Affiliated Cancer Hospital of Harbin Medical University to investigate the effect of this surgical method on bleeding, postoperative phantom limb pain and related complications.

Methods:

The femur and the soft tissue of the thigh are the sites with high incidence of bone and soft tissue sarcoma. For tumors with major vascular and nerve involvement and large invasion, extensive local resection cannot reach safe surgical boundaries, and hip dissection and hemi-pelvic amputation still occupy an important position in the treatment of locally advanced sarcoma of the thigh. Traditional amputation usually starts with separation of the main arteries and veins of the limb to block the blood supply of the limb in order to reduce the bleeding of the amputation, and the distal limb is in an ischemic state from the beginning to the end of the surgery, which may have adverse effects on the patient. By improving the surgical method, the main artery of the limb was ligated and severed near the end of the operation, and the distal limb of the amputated limb was in a non-ischemic state, and the effect of this surgical method on the amount of bleeding, postoperative phantom limb pain and related complications was investigated.

Ten patients with pathologically clearly diagnosed bone and soft tissue sarcoma practicing non-ischemic state hip amputation hip amputation between April 2019 and April 2021 at the Affiliated Cancer Hospital of Harbin Medical University, including 3 cases of modified hemipelvic amputation and 7 patients with hip disarticulation. 10 patients were followed up for 3-24 months, with an average of 13 months. Among them, 5 were male and 5 were female; their ages ranged from 18 to 69 years, with a mean age of 46 years. All patients had a clear preoperative pathological diagnosis. The pathological types included osteosarcoma in 3 cases, highly differentiated chondrosarcoma in 3 cases, soft tissue mucinous fibrosarcoma in 2 cases, synovial sarcoma in 1 case, and epithelioid sarcoma in 1 case. According to the American Joint Committee on Cancer Staging (AJCC) tumor staging: stage IIB in 4 cases and stage III in 6 cases. All patients underwent preoperative MRI and CT examination to assess the size and location of the tumor, chest CT, whole abdominal ultrasound and bilateral inguinal lymph node ultrasound examination to exclude tumor metastasis, and all cases in this group were free of distant metastasis and regional lymph node metastasis.

In the conventional surgery group, the main artery and vein are ligated at the beginning of the surgery, while in the non-ischemic amputation group, the main artery and vein of the limb in the operation area are
revealed and protected first, and the muscle tissue is severed layer by layer, and the sciatic nerve is revealed and protected, and after all the muscle tissue in the amputation area is severed, the sciatic nerve is routinely severed, the artery and vein are ligated, and finally the pelvic or hip capsule and skin are severed from the limb. In hip amputation surgery, for example, the affected limb is placed in a flat position with the hip padded, and the femoral artery and vein at the inguinal level are firstly revealed and protected, and the femoral nerve can be severed first. The anterior thigh and medial thigh muscles were isolated separately, and the iliofemoral muscle at the lesser trochanter was isolated and the surrounding venous plexus was ligated in the semi-flexed position of the hip and knee, with attention to the protection of the sciatic nerve at the posterior aspect of the lesser trochanter, and the posterior lateral hip capsule was revealed and incised. In hip and knee flexion position, the gluteus maximus and the gluteus minimus at the greater trochanter, the external rotation and posterior rotation muscles are dissected, the posterior lateral hip capsule is revealed and dissected, the posterior lateral joint capsule is revealed and dissected, the biceps femoris and semimembranosus semitendinosus on the posterior side of the thigh can be revealed and dissected, only the sciatic nerve and the posterior skin subcutaneous tissue and the femoral artery and vein are left, the femoral artery is ligated first and then the femoral vein is ligated. The femoral artery was ligated first, then the femoral vein was ligated, then the sciatic nerve was routinely severed, the lower limb was gently tractioned, and the subcutaneous tissue of the posterior thigh connected to the limb was fully exposed, and the subcutaneous tissue was severed first through the surgical incision in front of the skin design, then the skin was cut and the limb was severed. After surgery, all patients were placed with negative pressure drainage, and the tube was removed when the 24-h drainage was less than 20 ml. The patient was given a pneumatic pump for 3 days and oral rivaroxaban 10 mg/day for 14 days to prevent deep vein thrombosis in the lower extremity, and was taken off crutches 2-4 weeks after surgery. Chemotherapy was given according to the postoperative pathological results. All patients recorded surgical bleeding, 7 days postoperatively, and phantom limb pain was assessed using visual scoring at 3 months postoperatively; reviewed every 3 months for 2 years postoperatively and every 6 months thereafter, including chest CT scan to exclude lung metastases; liver ultrasound and lymph node ultrasound were performed to exclude liver metastases and lymph node metastases, and local magnetic resonance examination of the operated area to exclude local recurrence.

Results:

Ten patients were followed up for 3-24 months, with a mean of 13 months. All patients had no postoperative bleeding secondary surgical complications and none had postoperative infections. Postoperative flap necrosis occurred in one patient with a modified hemipelvic amputation, and no flap necrosis occurred in a patient with a hip disarticulation. In the non-ischaemic modified hemipelvic amputation group, the operative time was 4.5-5.5h, with a mean of 5h, and the operative bleeding volume was 300-1000ml, with a mean of 700ml; in the hip disarticulation group, the operative time was 2.5-3.5h, with a mean of 2.9h, and the operative bleeding volume was 300-450ml, with a mean of 357ml; phantom limb pain in the non-ischaemic amputation group at 7 days postoperative VAS pain score 4 - The mean VAS pain score was 4.5 out of 6; the mean VAS pain score was 3-4 out of 3 months after surgery. The
tumors in the amputated patients were large, and the imaging changes were locally advanced, invading the interstitial ventricles, encircling or invading vascular nerves or bone. The tumours ranged from 20 to 28 cm in diameter, with a mean diameter of 24.3 cm. 6 of the hemi-pelvic amputation tumours were seen to have invaded the hip joint in the gross specimens. 7 patients underwent post-operative chemotherapy, 2 patients developed lung metastases during the follow-up period and there was no local recurrence. The three hemi-pelvic amputees did not wear prostheses during the follow-up period, while five patients with hip disarticulation wore prostheses, and all patients were able to walk with crutches and take care of themselves.

Discussion:

Bone and soft tissue sarcoma is a malignant tumour of mesenchymal origin that occurs in the extremities or pelvis. Tumours in the shoulder girdle that involve important neurovascular vessels and invade large areas of soft tissue cannot be treated with limb preservation and require radical amputation. Traditional amputation usually begins with the isolation of the major arteries and veins of the limb, which are ligated at the beginning of the procedure to block the blood supply to the limb in order to reduce bleeding during the amputation. There is also the option of delaying the ligation of the vein to allow some blood to return before the main vein is blocked and ligated. Our approach is to leave the arterial veins unligated at the start of the amputation to preserve the blood supply to the amputated limb and then, after all the muscle tissue has been dissected, to disconnect the vascular bone and nerves to complete the amputation in a non-ischaemic state.

Malignant bone and soft tissue tumours have a high incidence in the femur and soft tissues of the thigh. Although limb-preserving treatment with tumour resection and reconstruction is the main direction of modern surgical treatment of sarcoma, for tumours with major vascular and nerve involvement and extensive invasion, extensive local excision cannot achieve a safe surgical border. Hemi-pelvic amputation and hip dissection are usually used in extensive or radical amputations to treat primary sarcoma lesions [3], with modified hemi-pelvic amputation being more indicated for larger tumours limited to proximal femoral acetabular involvement. Hemipelvic amputations are relatively risky and must be performed with caution in palliative care [4, 5]. Previous studies have shown that younger patients are more likely to benefit from hemipelvic limb amputation in terms of survival and function [5, 6]. Early hemipelvic limb amputation is more invasive and may be associated with higher surgical bleeding due to the limitations of the surgical approach and haemostasis at the time. The average intraoperative and postoperative bleeding pressure in a group of pathologies studied by Harold [7] et al was about 4000 ml. With improved surgical techniques, the amount of surgical bleeding in patients undergoing internal hemipelvic resection is now gradually decreasing and Tiwari [8] et al reported an average of 1300 ml of blood loss in patients undergoing computer assisted internal hemipelvic resection. Because effective anaesthesia was not available, amputations had to be done quickly and within minutes, and the wound was cauterised with a branding iron to stop bleeding after the amputation. That era produced brilliant
medical barbers like Pare, later called the father of surgery, who invented the early vascular clamp that could be used to stop bleeding by clamping the major blood vessels of the limb during rapid amputation [9]. Early rapid amputation without adequate anaesthesia is akin to amputation in a non-ischaemic state, where the limb is rapidly disarticulated and there is no ischaemic state in the distal part of the disarticulated limb, nor is there any pathological reaction due to prolonged ischaemia of the limb. Although haemostatic forceps or other methods are available to help stop bleeding after amputation, this ancient method of amputation is not suitable for use in modern hospital operating theatres. It is only in exceptional circumstances that this rapid pre-hospital amputation may be undertaken to save lives, and patients may benefit from emergency pre-hospital amputation when prolonged removal is not possible due to limb entrapment or haemodynamic restriction [10, 11].

At that time, in the absence of effective anaesthesia, amputation had to be done quickly to reduce pain and bleeding. After Payer's invention of the haemostatic forceps, amputations could be completed with haemostasis of large vessels and wounds [9], it was still customary to ligate the major limb arteries before dissecting the muscles in order to reduce surgical bleeding. Our view is that modern surgery, with adequate anaesthesia, is perfectly suited to non-ischaemic amputation of limbs, i.e. to effectively control bleeding without allowing ischaemia in the dissected limb, thereby reducing ischaemia in the neuromuscular and other tissues. The approach is to achieve a non-ischaemic amputation by dissecting the major blood vessels of the limb after the amputation is almost complete. The anterolateral flap hemipelvic amputation is in fact an intermediate non-ischaemic amputation, except that the anterolateral thigh flap, which preserves the femoral artery, is used to cover the hemipelvic amputation when the posterior hip flap cannot be used. Niu Xiaohui[12] et al. concluded that anterolateral flap hemipelvic amputation, unlike conventional hemipelvic amputation in which the external iliac and femoral vessels must be preserved during surgery, had an average intraoperative bleeding of 2300 ml. Although the anterolateral flap hemipelvic amputation was even more invasive than conventional hemipelvic amputation, the average bleeding was significantly reduced compared to conventional hemipelvic disarticulation amputation.

The three modified hemi-pelvic amputations we performed with non-ischaemic transitions were similar to anterolateral flap hemi-pelvic amputations in that the external iliac vessels were not ligated at the start of the surgical dissection and were only ligated after all muscle tissue had been dissected, and then the nerves and iliac bone were dissected to complete the amputation, with an average intraoperative bleeding of 700 ml (300-1000 ml).

The effect of hemi-pelvic amputation and hip disarticulation may be closely related to the presence of abundant collateral blood loops around the hip and shoulder joint, which have been shown by modern anatomy to be widespread. The hip is surrounded by branches of the internal and external iliac arteries and the femoral artery, which form a rich network of anastomosing arteries. Usually the medial and lateral femoral arteries, the superior and inferior gluteal arteries and the first penetrating artery of the deep femoral artery are located on the deep surface of the gluteus maximus, near the femoral square and the greater trochanter, forming the "hip cross anastomosis". In addition, in the lateral wall of the pelvis near
the hip joint, there are also the deep iliac artery, the lumbar iliac artery, the lateral sacral artery, the median sacral artery and the anastomosing branches between them. Arterial anastomoses between the sides of the intrapelvic organs are also abundant [13].

In our clinical work we have carried out ultra-delayed blocking of the major arteries and veins of the limb for hip disarticulation and hemipelvic amputation, which may also be applicable to periacetabular disarticulation amputations because of the presence of this same collateral circulation around the shoulder joint [14, 15]. Unlike a traditional amputation, there is no need for a special assistant to lift the limb and make a posterior incision to dissect the posterior musculature and then sever the sciatic nerve. Our surgical operation is performed entirely from the anterior surgical incision and continues until the limb is severed by cutting the skin of the posterior thigh from the deep side of the anterior incision, which can be done by two people. Similar to early rapid amputation, the limb is cut directly from the anterior side, but it is different in that different tissues are cut in sequence, with all the muscles being cut first, then the nerves (the femoral nerve is mainly a motor nerve and can be cut first, while the sciatic nerve is a major sensory and motor nerve, so it is cut later), and finally the arteries and veins are cut, which has almost no effect on the whole limb and even on the normal haemodynamic changes in the body, so it may be possible to reduce intraoperative bleeding from the trauma surface. There is an extensive arterial network of anastomosing branches around the hip joint and blocking the main artery of the limb cannot achieve complete blockage of the blood supply to the limb. After blocking the proximal end of the arterial trunk, the pressure at its proximal arterial end will increase significantly and the body's compensatory increase in collateral circulation pressure and blood volume can lead to increased blood supply to the tissues around the hip joint, which may result in increased bleeding from the surgically dissected tissue.

The key to less bleeding during amputation is trauma haemostasis. By ligating the main arterial vein, the arterial branches are still present and the venous pressure may be increased, which in turn increases the risk of bleeding. The risk of causing passive compression of the tumour is reduced by reducing extrusion of the limb to move, i.e., by reducing interference with the tumour and reducing the increase in venous pressure in the tumour area. Anatomy has demonstrated that there is an abundance of collateral circulation in the human compensatory arteries in the hip, shoulder, pelvis and scapular girdle, and in tumourous lesions the collateral circulation around the tumour lesion is even more pronounced. Pre-emptive preservation of the major arteries and veins during amputation, without disturbing the circulatory pathways of the limb, reduces the amount of blood supplied to the tissues by the collateral circulation, and then excision of the dissected tissue may reduce bleeding and oozing from the wound. This type of non-ischaemic amputation is not suitable for amputations resulting from severe ischaemia or disfigurement of the limb, but is more appropriate for oncological amputations.

Amputation surgery has evolved from the earliest days of rapid dissection to hemostasis followed by dissection, and the modern method of blocking major limb vessels followed by dissection of other tissues is still used. The non-ischaemic approach to periacetabular amputation may be tried for radical amputation of sarcomas at other sites, and perhaps more clinical data to explore the effects of surgical
bleeding and postoperative phantom limb pain compared with traditional amputation methods may yield good results.

**Abbreviations**

A: artery; V: vein; N: sciatic nerve; P: pefvis

**Declarations**

- **Ethics approval and consent to participate:** Written informed consent was obtained from all participants, and the study was approved by the Ethics Committee, Hospital of Oncology, Harbin Medical University, Harbin, China (acceptance number: ) in accordance with the tenets of the Declaration of Helsinki

- **Consent for publication:** Not applicable.

- **Availability of data and materials:** The datasets used during the current study are available from the corresponding author on reasonable request.

- **Competing interests:** The authors declare that they have no competing interests

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- **Authors’ contributions:** Qing Yu Shi, Rang Zhou and Yang Sun cared for the patients and performed surgery. Rang Zhou, Qing Yu Shi, Yang Sun and Zhihao Pan designed and drafted the manuscript. All authors read and approved the final manuscript.

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- **Non-ischemic hip amputation has some advantages in sarcoma treatment.**

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Figures

- **Figure 1**
  - Modified hemipelvic amputation in non-ischemic conditions
  - 1 An intraoperative anterolateral incision was made and the external iliac artery was kept patent, A: artery; V: vein.
  - 2 Intraoperative posterior lateral incision, visible sciatic nerve, N: sciatic nerve
  - 3 Pelvic section after limb dissection, P: pelvis
  - 4 Preoperative CT image shows tumor in the acetabulum
  - 5 Post-modified hemipelvic amputation x-ray performance

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See image above for figure legend.