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En-bloc resection of scapular chondrosarcoma with intraoperative computer navigation

En-bloc resekcija hondrosarkoma lopatice z uporabo intraoperativne računalniške navigacije

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Abstract

Background: Surgical removal of scapular tumours presents a complex problem due to the vicinity of major nerves and blood vessels and its functional importance. Planning such a procedure presents a significant challenge, further complicated by varia-bles such as histological findings, tumour location, and size. In recent years, the development of 3-D imaging, modelling, and printing has proven to be helpful in planning and improving the safety and accuracy regarding major anatomical structures and minimalisation of healthy tissue resection. With modern modalities, we can more readily adhere to the recommendation of limb-salvage surgery. So far, computer-navigated surgery has been used for chondrosarcoma resections of long bones, pelvis, sacrum, and spine, but very few reports provide insight into scapular chondrosarcoma resections using computer navigation.

Case presentation: We present a case of a 36-year-old male with a secondary chondrosarcoma grade 1, where "en bloc" resection was successfully performed by using MR- and CT-based intraoperative computer navigation.

Discussion: Surgery remains the sole treatment for chondrosarcomas, aiming for complete tumour resection with negative margins while preserving limb function. Successful use of surgical navigation has been documented in various bones, yielding precise bony resection but not soft tissue margins.

Conclusion: We applied principles of chondrosarcoma treatment to scapular chondrosarcoma, achieving functional shoulder preservation. Combining navigation with PSI could enhance surgical outcomes, though challenges include technology availability and variability in patient cases.

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Ključne besede: hondrosarkom; hondrosarkom ramenskega sklepa; totalna resekcija en bloc; računalniško vodena navigacija; ohranitvena kirurgija

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Izvleček

Izhodišča: Kirurška odstranitev tumorjev lopatice je kompleksen problem zaradi bližine pomembnih živcev, žil in funkcijske pomembnosti. Načrtovanje takega posega je velik izziv, ki ga dodatno otežijo spremenljivke, kot so histološke ugotovitve, mesto tumorja in njegova velikost. V zadnjih letih se je razvoj 3-D slikovnih preiskav, modeliranja in tiskanja izkazal kot uporabna tehnologija pri načrtovanju, izboljšanju varnosti in natančnosti posegov pri pomembnih anatomskih strukturah in odstranitvi čim manj zdravih tkiv. S sodobnimi sredstvi lahko pogosteje in bolj natančno upoštevamo priporočila ohranitvene kirurgije. Doslej se je računalniško vodena kirurgija uporabljala pri resekciji hondrosarkomov dolgih kosti, medenice, križnice in hrbtenice, toda zelo malo je poročil o uporabi računalniške navigacije pri tumorjih lopatice.

Predstavitev primera: Pri 36-letnem moškem s sekundarnim hondrosarkomom gradusa-1 smo uspešno opravili t. i. ''en bloc'' resekcijo s pomočjo računalniške navigacije med operacijo, osnovane na CT in MRI.

Razprava: Kirurška oskrba je edino dokončno zdravljenje hondrosarkomov s ciljem popolno odstraniti tumor s tumorsko negativnimi robovi, a hkrati ob ohranitvi funkcije uda. Uspešno uporabo kirurške navigacije na različnih kosteh so že opisali in poročali o natančni resekciji kostnine, ne pa nekirurške navigacije tudi brez mehkotkivnih robov.

Zaključek: Z uporabo načel zdravljenja hondrosarkomov ob uporabi računalniško vodene navigacije smo pri zdravljenju hondrosarkoma lopatice ohranili ra-mensko funkcijo. Združitev navigacije in PSI bi lahko izboljšala izide operacij, a izzivi, kot so dostopnost tehnologije in variabilnost med primeri, so še vedno prisotni.

1 Introduction

The second most common primary malignant tumour of bone requiring surgical treatment is chondrosarcoma (1,2), 20% of which develops in the shoulder girdle (2). With surgical resection being the definitive treatment (1-5) and the functional outcome varying on the surgical technique and location of the resected part (1,2), the outcome is more favourable if the glenohumeral joint can be preserved (1-3). As imaging and computer rendering of images evolve, surgical options become more abundant. With MR- and CT-based navigation and other navigation techniques, we might be able to spare certain patients from total scapulectomies and unnecessary radical healthy tissue resection, which have been shown to have worse functional and aesthetic outcomes than joint-saving procedures (1-4).

Although computer navigation surgery is common in shoulder arthroplasty, where it has shown its practicality (5), not much has been reported on its use in scapular tumour surgery. So far, we have found only one case report by Deng et al. (6) of using 3-D imaging and printing to produce patient-specific partial scapular prosthesis and navigation template. In this case report, we detail the inaugural case of scapular chondrosarcoma limb-preserving surgery employing intra-operative MR- and CT-based navigation (Ekliptik, Slovenia, EU) (7). Our surgical approach aims to preserve critical functional segments of the scapula, thereby optimizing postoperative functional outcomes. By leveraging the precision and enhanced visualization afforded by intra-operative navigation, this technique aligns with contemporary surgical practices focused on maximizing musculoskeletal integrity and function in complex oncological resections. We decided to use MR- and CT-based -navigation to increase the accuracy of surgical resection and improve the odds of preserving the glenohumeral joint and other functionally important parts of the shoulder joint and girdle.

2 Case presentation

A healthy 36-year-old male without chronic diseases was administered and examined in the orthopedic emergency department due to a growing mass in the right supraclavicular fossa. He described mild discomfort during hiking with hiking poles and an occasional tingling sensation in the right arm. Upon inspection, a solid, painless, and immovable resistance was palpable above the clavicle. The skin was not showing signs of inflammation or necrosis, and no neurological deficits were found except for occasional paresthesias in extreme shoulder positions.

Ultrasonography imaging showed an 8 x 7 cm tumour formation in the area of the medial clavicle cortex with signs of calcification and ossification. The patient was referred for an MRI, which showed a lobular tumour formation 9 x 9 x 4.5 cm in size, protruding from the coracoid process and anteriorly touching the clavicle but showing no invasion into the cortex. Apically, it was almost at the height of the m. trapezius,

distally to the third rib, with possible invasion of m. subscapularis. Signs of mild atrophy of m. supraspinatus and infraspinatus were also present and accredited to the n. suprascapularis entrapment.

Two consecutive core needle biopsies through the same incision were conducted, and both came up as inconclusive. Additionally, a PET-CT was conducted, which showed a mild metabolic increase in regions of tissue where calcination was ongoing but could not be differentiated as malignant or benign. A tumour board with oncology specialists was held where it was decided to perform an open incision biopsy under general anesthesia. An open biopsy was conducted, and a yellowish multi-fragment sample of a combined volume of 6 x 5 x 1.5 cm was obtained. The histopathological analysis of open biopsy resulted in a differential diagnosis of either periosteal chondroma or periosteal chondrosarcoma grade 1. Due to slow, permanent tumour growth, large tumour size, and aggressive radiological features, the tumour board proposed "en bloc" wide-margin resection of the tumour as the best treatment option, whereby it was estimated that the glenohumeral joint could be preserved.

An international expert-to-expert teleconference meeting was additionally organized with a reference sarcoma expert, Prof. Dr. Med. et Dr. Sc. Nat. Bruno Fuchs, Luzern, Switzerland, in order to clarify the indication and details of the surgical plan with function-preserving wide resection and preservation of the glenoid and the inferior angle of the scapula.

Planning was done by using a commercial MR- and CT-based navigation software for osteotomies, Guiding Star – Ekliptik (7). First, a virtual 3-D model was rendered from MR and CT imaging with the tumour being marked (Figure 1).

After careful consideration and MRI imaging, a wide portion of the scapula above and anteriorly of the spina scapularis was marked for resection along with the coracoid process and the medial and distal part of the clavicle, but with the glenoid and the shoulder joint remaining intact. Three planes of excision were later marked (Figure 2). A preoperative 3D computer model of the resected scapula was also made as a reference.

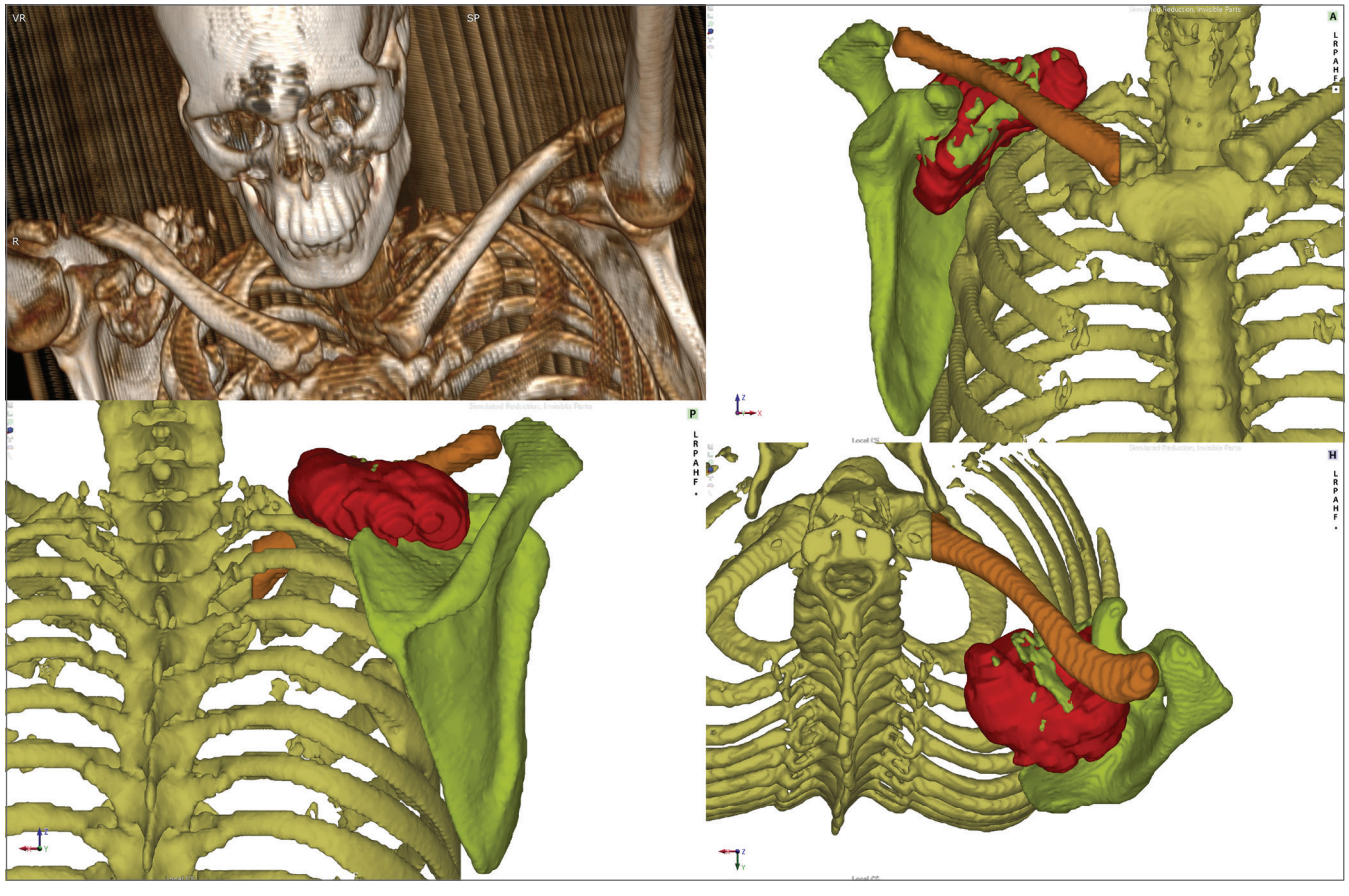

Figure 1: Virtual 3-D model rendered from MR and CT imaging with marked tumour.
Source: archive of the Department of Orthopaedic Surgery, University Medical Centre Ljubljana.

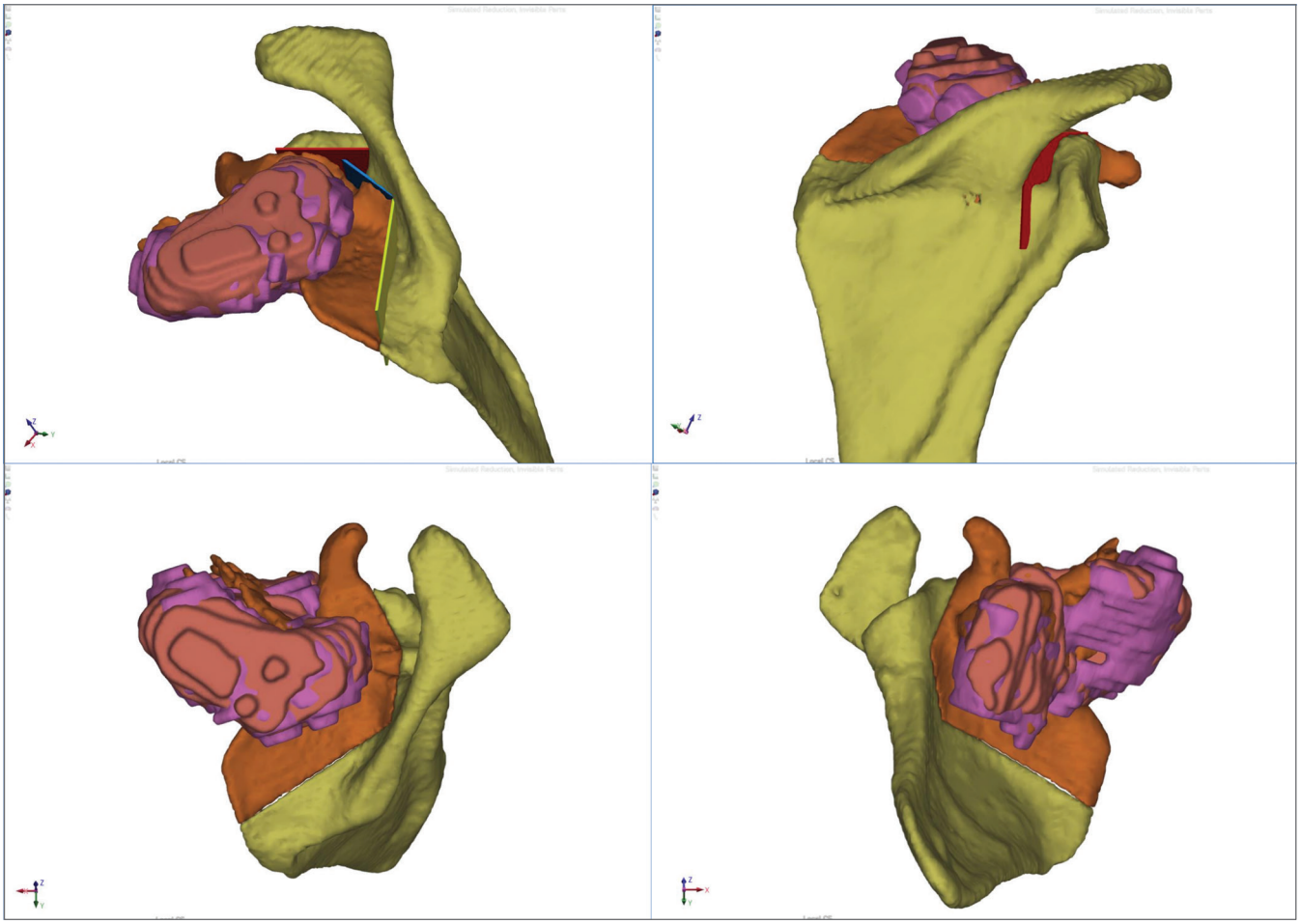

Figure 2: Three planes of excision marked on the 3-D model in different views.
Source: archive of the Department of Orthopaedic Surgery, University Medical Centre Ljubljana.

The surgical procedure was performed in the beach-chair position under general anesthesia. An anterior/posterior approach was utilized, similar to the Tikhoff-Linberg resection. Scapula mobilization was done by m. trapezius release so that the fossa supraspinata with m. supraspinatus could be explored and thoroughly assessed. After scapular mobilization, an anterior approach was utilized to mobilize the vessels and nerves and expose the clavicle, where osteotomy was performed in the medial part of the diaphysis. After the scapula and crucial soft tissue release, a special probe was inserted into the healthy bone of the posterior part of the scapula, and an imaging calibration scan was done. Subsequently, an intraoperative computer navigation was used to guide K-wires as reference points for the osteotomy planes and cuts in the scapula. During the operation, a major decision to keep the coracoid's distal portion was made to keep the insertions of the biceps short head and m. coracobrachialis intact. The resected part with the insertions was fixated anteriorly next to the glenoid, thus preserving the muscles and most of their function. The osteotomy gaps were not grafted, and the medial portion of the clavicle was left in situ without fixation. A final navigation-guided assessment was done, which showed the desired resection with optimally placed cuts. After resection, an X-ray image of the resected tissue (Figure 3) was taken.

Following the procedure, a standard postoperative regimen was followed. A six-week follow-up showed good recovery, slight edema of soft tissues was present without palpable tenderness, and active abduction and flexion of 40 degrees was achieved. A six-month follow-up showed great rehabilitation, active abduction of 90 degrees, flexion of 160 degrees, external rotation of 50 degrees, and internal rotation with reach to the thoracic spine. The elbow, wrist, and finger joints showed no deficit in function compared to the healthy arm.

The histology report of the removed tumour

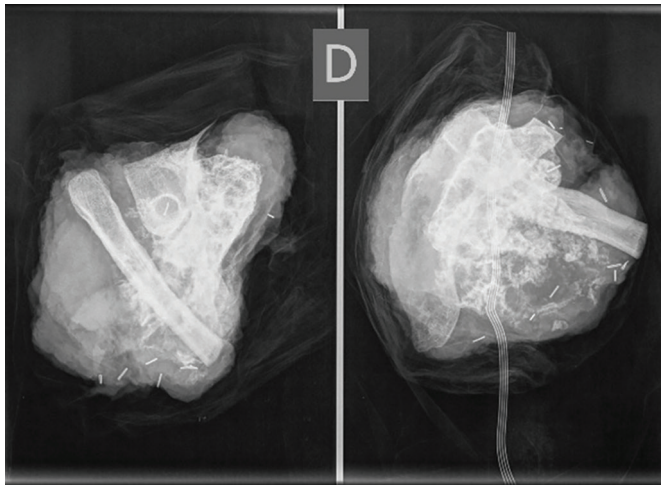

Figure 3: Postoperative X-Ray of the resected tissue.
Source: archive of the Department of Orthopaedic Surgery, University Medical Centre Ljubljana.

confirmed a successful wide resection with no presence of tumour cells in the resection margin and the diagnosis was periosteal chondrosarcoma grade 1. The postoperative Mesenchymal tumour board decided that no chemotherapy or radiotherapy was needed since the tumour was entirely removed "en bloc", no metastasis was found prior to surgery and its grade and histological findings were favourable. They suggested regular CT and X-ray imaging of the lungs following the sarcoma follow-up protocol. The patient is to continue his rehabilitation with regular checkups. Currently, no further surgical or oncological intervention is required.

3 Discussion

Surgery is currently the only treatment option for chondrosarcomas. The presented case shows how diagnostics of cartilagineous tumours cannot rely on histopathological analysis alone, and correlation with image interpretation by an experienced radiologist is mandatory to correctly assess the tumour's aggressivenesstumour (8). Achieving complete tumour resection with negative margins is the primary surgical goal, preferably by preserving limb function. So far, successful use of surgical navigation has been documented in treating chondrosarcomas of long bones, pelvis, sacrum, and spine (9-15), with reported benefits mostly being tumour-free margin resection of bony structures (9,10,12,15). However, no benefit was shown for achieving adequate soft tissue margin resection (9,10). A systematic review by Bruschi et al. (9) has shown that both, intraoperative surgical navigation and patient-specific instrumentation (PSI), yield comparable results in achieving accurate tumour margin resection with the major drawbacks being the length of preoperative planning and jig production in the case of PSI and surgery time in case of intraoperative navigation use. As the benefits of surgical navigation have been shown in the aforementioned regions, we decided to extrapolate the same principles to our case of scapular chondrosarcoma. Our reasoning stands on the fact that in our case, the tumour was expanding anteriorly in such a way and extent that with precise resection, we could keep most of the glenohumeral joint intact along with functionally important structures such as the coracoid process and the surrounding nerves. Also, one of the strong points for using MR- and CT-based navigation in regions such as the pelvis, sacrum, and spine is the regional anatomical complexity and the navigation benefit of better visualization of the bony topography, which we could use in the scapula resection.

By using MR- and CT-based navigation, we could adhere to the principles of joint and limb preserving surgery and, as shown in our case, keep most of the shoulder and upper limb function by preserving the glenohumeral joint and adjacent muscle insertions crucial for upper limb function. It is important to note that in cases where tumour expansion occurs in the dorsal and/or apical direction, the proposed approach would be deemed suboptimal. In such scenarios, palpation and resection of the tumour would be more feasible, allowing for the precise maintenance of the required surgical margins by using regular intraoperative X-ray imaging. Furthermore, integrating patient-specific instrumentation (PSI) and advanced surgical navigation systems could synergistically enhance surgical outcomes. Such a combination could facilitate significantly faster surgery times and mitigate intraoperative challenges, such as the precise placement of jigs and sensors, ultimately leading to superior cut accuracy and increased operational efficiency. Nevertheless, the disadvantage of PSI is the need for wide exposure of bone and removal of adjacent soft tissues close to the tumour in specific anatomical locations, such as presented in our case report. The benefits of partial resection using surgical navigation could be augmented by using 3-D patient-specific prosthesis of the scapula similar to what was shown by Deng et al. (6) in their case report. One of the major drawbacks is the lack of worldwide availability of the technology (12). Research in this domain is further impeded by the

relatively limited patient pool, coupled with significant variability in tumour size, type, expansion patterns, and the associated risks of incomplete resection and its sequelae. We recognize the potential of multicenter studies to mitigate these challenges by expanding the patient pool, thereby enhancing our understanding of tumour surgery and refining its established principles through integrating contemporary technological advancements. Nonetheless, it is acknowledged that this approach to data collection and research is fraught with numerous complexities and logistical challenges.

4 Conclusion

Surgical navigation shows promise in achieving precise resection of chondrosarcomas, particularly in complex anatomical regions such as the pelvis, sacrum, and spine. Our case extends these benefits to scapular chondrosarcoma, demonstrating the potential for joint and limb function preservation. However, the technique is less effective for soft tissue margin resection and presents challenges such as prolonged preoperative planning and surgery time. Integrating patient-specific instrumentation (PSI) and advanced navigation systems could enhance surgical accuracy and efficiency, though the availability of such technology is limited. Future multicenter studies are essential to validate these findings, optimize surgical techniques, and improve patient outcomes through advanced imaging technology. This case could help guide future applications, demonstrating the potential for improved surgical precision and patient outcomes by integrating cutting-edge imaging technology.

Conflict of interest

None declared.

Informed consent of the patient

The patient gave informed consent for the publication of his case.

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