



A retrospective validation of an imaging protocol for the management of solitary central cartilage tumours of the proximal humerus and around the knee



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AIM: To validate an imaging protocol for the management of solitary central cartilage tumours (CCTs) of the proximal humerus and around the knee.

MATERIALS AND METHODS: Over a 10-year period, 387 patients were identified with a CCT in the proximal humerus, distal femur, and proximal tibia, who were referred to a single unit either from primary/secondary care or tertiary care directly to Royal Orthopaedic Hospital, a specialist orthopaedic oncology service. The initial magnetic resonance imaging (MRI) images and any follow-up images were evaluated for length of tumour, presence/absence of endosteal scalloping, or aggressive/malignant features. The cases were categorised into one of seven types according to the Birmingham Atypical Cartilage Tumour Imaging Protocol (BACTIP). The outcome in the cases was assessed to ascertain if application of the protocol would have led to any delay in the diagnosis of malignant transformation to a chondrosarcoma.

RESULTS: The incidence of malignancy (chondrosarcoma) increased with ascending BACTIP. There was a 100% benign diagnosis (enchondroma) in types IA and IB, 96% in IIA, and 83% in IIB. Fifty-seven percent of type IIC and 97% type III were diagnosed as malignant. In only one case would the application of the protocol have led to a 5-month delay in the diagnosis of chondrosarcoma.

CONCLUSIONS: This retrospective study confirms the BACTIP as a useful tool for the general radiologist in the initial assessment of CCT in the proximal humerus and around the knee with the exception of the proximal fibula. In particular, determining which cases need prompt referral to a specialist orthopaedic oncology service for further assessment.

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Introduction

Central cartilage tumours (CCT) of bone range from the common benign enchondroma to the uncommon chondrosarcoma. Rarely, over time, an enchondroma may undergo malignant transformation to a chondrosarcoma.^{1–4} The distinction of enchondroma from intermediate (grade

2) and high-grade (grade 3) chondrosarcoma on imaging is relatively straightforward,^{5,6} but differentiating enchondroma from low-grade (grade 1) chondrosarcoma remains challenging.^{7–10} A recent review article published in this journal highlighted how initial optimism for advanced imaging techniques in this clinical context has been shown more recently to be unjustified at least on a routine basis.¹¹ These include static contrast-enhanced magnetic resonance imaging (MRI),^{9,12} dynamic contrast-enhanced MRI^{13,14} diffusion-weighted MRI,¹⁵ bone scintigraphy,¹⁶ and 2-[¹⁸F]-fluoro-2-deoxy-D-glucose (¹⁸F-FDG) positron-emission tomography (PET).^{17,18} The conundrum is further compounded by the fact that histological distinction of the two conditions is equally problematic. This may be due to sampling error of the needle biopsy^{19,20} but studies have also confirmed the long recognised view that interobserver variation even amongst experienced bone pathologists can be very variable.^{21,22} In an attempt, therefore, to bring clarity to a diagnostic dilemma Patel and co-workers recommended a pragmatic approach to CCTs at the commonest sites in the proximal humerus and around the knee. They proposed an imaging protocol (Birmingham Atypical Cartilage Tumour Imaging Protocol [BACTIP]; Fig 1) for the initial imaging assessment with non-contrast-enhanced

MRI and follow-up for CCTs at these two sites.¹¹ Although employing a common-sense approach, the protocol has a drawback in that it is not currently clinically validated. The purpose of this study is to provide that validation by retrospectively reviewing a large cohort of CCTs arising in the proximal humerus and around the knee and assessing what happened to these cases over a prolonged time period.

Materials and methods

This study was performed in a centre with a large general orthopaedic practice as well as a long established supra-regional orthopaedic oncology service. Hospital review board approval was granted for the retrospective data analysis used in this study. The text of the radiology reports for MRI examinations of the shoulder and knee from the commissioning of the picture archiving communications system (PACS) in September 2007 through to the end of December 2016 was searched for the term enchondroma. The orthopaedic oncology unit’s database was also searched for the same time period to identify all patients registered with a final diagnosis of chondrosarcoma at the same anatomical sites. Surface cartilage lesions and

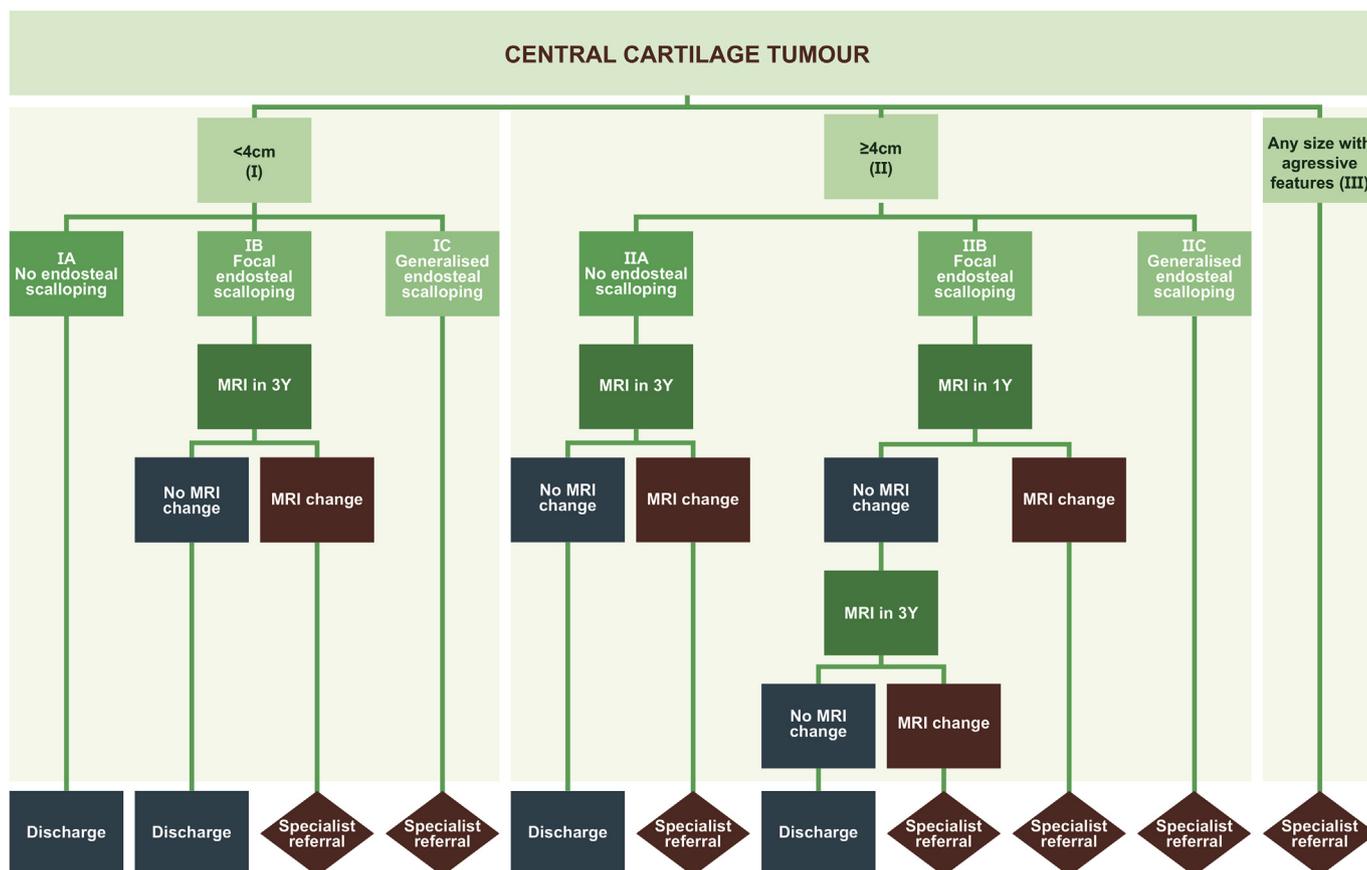


Figure 1 Birmingham Atypical Cartilaginous Tumour Imaging Protocol (BACTIP). Algorithm for the MRI management of CCTs of the proximal humerus and around the knee, excluding the proximal fibula. Note that this protocol has been modified since its original publication¹¹ to indicate type IC CCTs should now be referred on to a specialist orthopaedic oncology service. Key: Aggressive features = bone expansion and/or cortical thickening, periostitis, cortical destruction and a soft tissue mass. No aggressive features = absence of above criteria ± endosteal scalloping. MRI change = increase in longitudinal length of CCT > 1 cm, progression of endosteal scalloping and/or development of aggressive features.

enchondromatosis syndromes (e.g., Ollier disease and Maffucci's syndrome) were excluded as their biological activity differs from solitary enchondroma.

The patients were divided into two groups depending on source of referral. Group 1 comprised those with general orthopaedic complaints referred for MRI from primary (general practitioner) or secondary (orthopaedic surgeon/extended scope practitioners) care. Group 2 comprised those referred to the specialist orthopaedic oncology service (tertiary care) for management of a CCT already identified on an outside MRI examination.

Patient demographics including age, sex, and length of follow-up were recorded. The total follow-up time (TFUT) was determined as the time elapsed between the date of the MRI on which the CCT was first identified and 31 December 2018. This comprised a combination of "active" follow-up time (AFUT) and "passive" follow-up time (PFUT). The AFUT was determined as the time between the first MRI and the last available imaging of the relevant anatomy on the PACS, be it MRI or radiographs. The PFUT was the time elapsed between the last available imaging and known discharge of the patient from the care of the unit or, alternatively, 31 December 2018 during which period there was no record, in terms of further imaging on PACS, of re-referral to the unit. This meant a minimum TFUT for patients of 2 years.

The first MRI of all patients was reviewed by a single radiologist with >30 years of musculoskeletal MRI and specialist orthopaedic oncology experience, who was unaware at the time of the review of the final diagnosis in each case. The site of the CCT was identified and then two parameters were assessed according to the BACTIP (Fig 1).¹¹ These were the maximum length of the tumour and the presence or absence of endosteal scalloping. The cases were allocated, according to the protocol, to one of two categories with type I <4 cm and type II \geq 4 cm in length. Endosteal scalloping was defined as absent or present. If present, the degree of endosteal scalloping was defined as focal (<10% circumference of lesion based on the transverse image with the greatest involvement) or extensive (\geq 10%). Practically this involves selecting the transverse image where the endosteal scalloping is the greatest and superimposing a circle of best fit around the edge of the bone. Lines are drawn from the edges of the scalloped endosteum to the centre of the circle to give an angle from which the degree of endosteal scalloping as a percentage of the circumference can be calculated. Focal endosteal scalloping (<10% of the circumference of the circle) equates to an angle of <36°, extensive endosteal scalloping (\geq 10% of the circumference of the circle) equates to an angle of \geq 36°. If, on the chosen section, there are two or more areas of endosteal scalloping separated by normal bone then individual percentages of the scalloped areas are added together to give a total value. Absent endosteal scalloping was given the suffix A, focal B and extensive C. Thereby classifying the CCT as falling into one of six categories: types IA (Fig 2), IB (Fig 3), and IC and types IIA, IIB (Fig 4), and IIC (Fig 5). A seventh category, type III with no suffix, was reserved for those cases, irrespective of length, showing aggressive and

thereby potentially malignant features such as cortical destruction and soft tissue extension (Fig 6).

The reviewing radiologist sequentially assessed any further MRI images in each case, once again identifying the type and any changes in terms of length, endosteal scalloping or development of aggressive features. The final diagnosis was based on either consensus opinion on imaging and histological findings after radiological/pathological review post-image-guided biopsy or on imaging features alone with or without follow-up imaging. The three remaining authors, all musculoskeletal radiologists with orthopaedic oncology experience, blindly twice reviewed 25 selected cases from the overall series to assess inter- and intra-observer variation in assigning a BACTIP category as compared with the principal reviewer.

Results

Four hundred and twenty-three patients with a CCT in the proximal humerus or around the knee were identified. Thirty-six cases arising in the proximal fibula were excluded as the relatively small transverse area of this bone meant that all the CCTs were types IB or IC limiting the value of applying the BACTIP at this site. This left a total in of 387 cases. Five hundred and fifty-one MRI examinations were reviewed to give a mean of 1.4 examinations per patient (range 1–10 examinations). The mean number in types IA to IC was 1.3 examinations. This increased to 1.8 in type IIA, 1.6 in type IIB, 2.2 in type IIC, and 1.1 in type III. The lower figure in type III reflects the fact that most of these patients had a chondrosarcoma and so underwent definitive surgery after only a single examination followed by a biopsy. Any further examinations performed in these patients, as part of surgical follow-up, were not included in the analysis.

Fig 7 shows the distribution of cases per BACTIP type and group 1 for primary or secondary care origin patients and 2 for tertiary care/oncology patients. One hundred and seventy-six cases (45%) were classified as type IA (Fig 2). The numbers of patients in the other types dropped dramatically with only three cases of type IC. The percentage of group 1 cases also dropped from 47% in IA down to 13% in IB and zero from IC to III with the exception of types IIA with 3 (6%) and IIB with one case (2%).

The distribution of mean ages per BACTIP type and group is shown in Electronic [Supplementary Material Fig. S1](#). The mean age in all types was very similar, being towards the end of the fifth decade or early in the sixth decade, i.e., predominantly between the ages of 55 and 65 years (range 22–90 years).

The distribution by sex is shown in Fig 8. Overall there was a female to male ratio of almost 2 to 1 (65 : 35%). This was seen in all types with the exception of IC (too few cases) and IIA (56 : 44%). The female preponderance was over 4 : 1 in categories IIB and IIC, but almost equal in type III (52 : 48%).

The mean length of the CCTs per BACTIP type and group is shown in Electronic [Supplementary Material Fig. S2](#). As expected, because length is one of the parameters

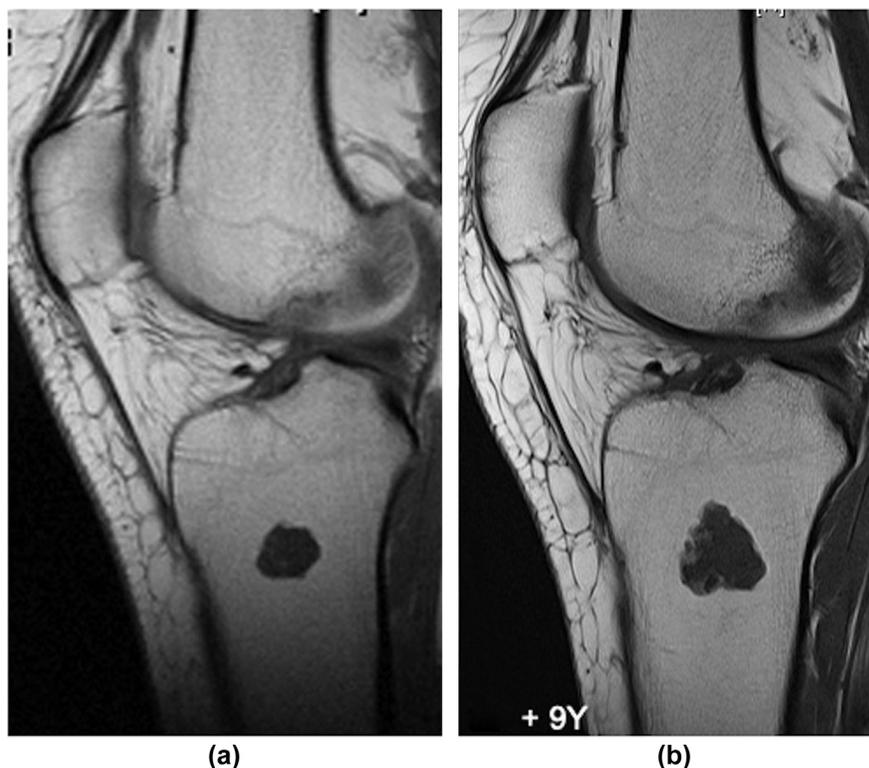


Figure 2 (a) Sagittal proton-density and (b) T1-weighted images obtained 9-years apart showing a type IA CCT increasing in size from 1.2 to 1.8 cm (50% increase).

measured, this increases as the types ascend. The mean length of the CCTs in the overall series is 4.3 cm, 1.9 cm for group 1, and 5.1 cm for group 2 patients.

The site of the CCT per BACTIP type is shown in the Electronic [Supplementary Material Fig. S3](#). Seventy percent or over of types IA and IB CCTs were identified in the distal femur with <20% in the proximal humerus and proximal tibia, respectively. The distal femur, still the commonest site

in IIA and IIB ([Fig 3](#)), had decreased to 54% in both types. The proximal humerus predominated in types IIC and III with 60% and 55%.

Twenty-one percent of the series underwent biopsy. The percentage biopsy rate per BACTIP type is shown in in Electronic [Supplementary Material Fig. S4](#). Only 2.3% of type IA and none of the IB cases underwent biopsy. All type IC cases (three patients) had a biopsy. The biopsy rate for IIA to

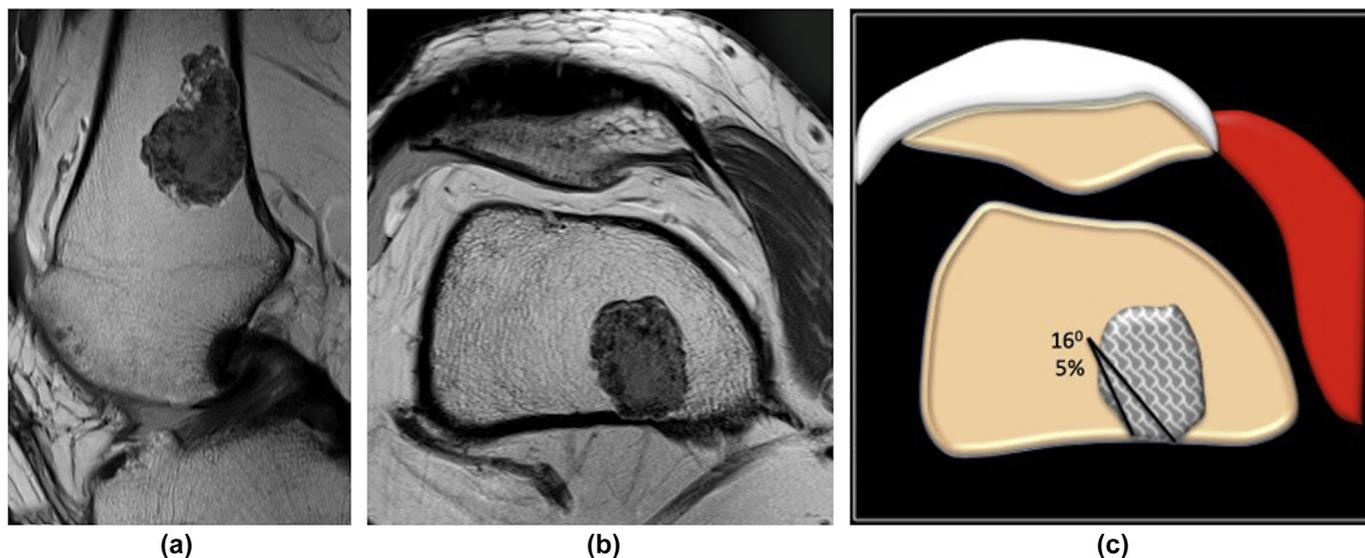


Figure 3 (a) Sagittal and (b) axial proton-density images, with (c) transverse schematic showing a type IB CCT 3.1 cm in length with focal endosteal scalloping.

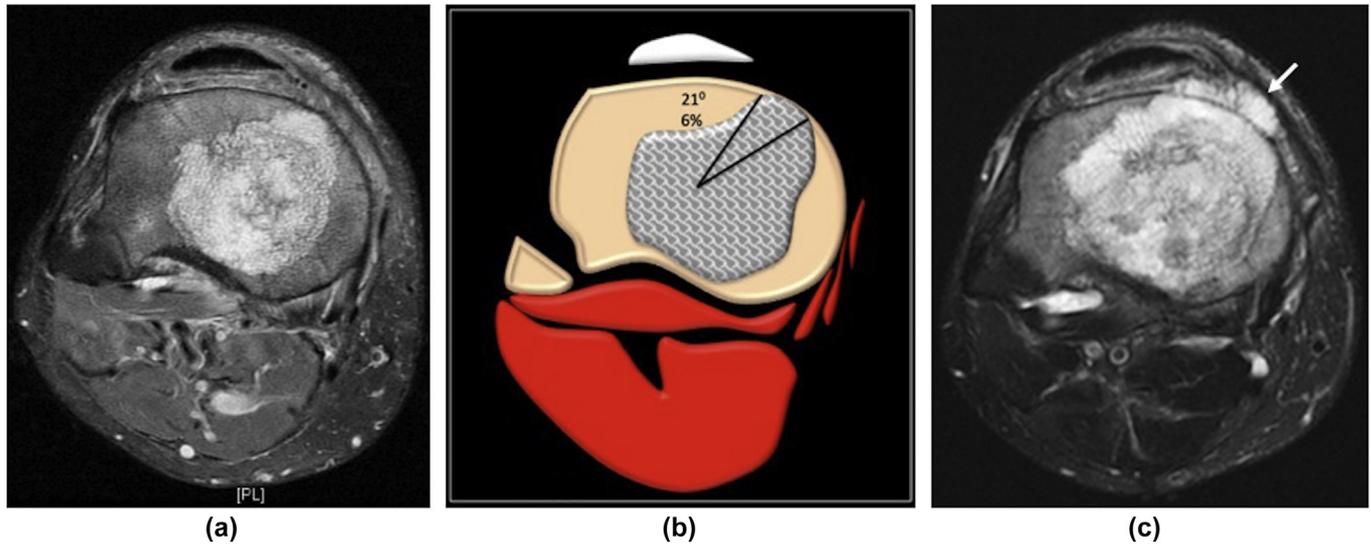


Figure 4 (a) Axial proton-density fat-saturated and (b) transverse schematic with (c) axial T2-weighted fat saturated images obtained 7-months later. The initial image shows a type IIB CCT but the follow-up image shows aggressive features with soft-tissue extension changing the lesion to a type III (white arrow). Biopsy revealed grade 2 chondrosarcoma.

IIC approximately doubled with each type (15%/36%/76%). All type III cases were biopsied.

The final diagnosis based on imaging alone or consensus agreement on imaging and histological findings is shown in Fig 9. As atypical cartilaginous tumour (ACT) and other labels such as “cartilaginous tumour of unknown malignant potential” (CLUMP) are now considered as synonymous with grade 1 (low-grade) chondrosarcoma,^{23,24} these have all been included under the latter title. One hundred percent of cases in types IA and IB were deemed to be enchondroma. This reduced to 96% for IIA and 83% for IIB cases with slightly more chondrosarcoma than enchondroma in type IIC. All but one of the type III cases were diagnosed as chondrosarcoma.

Fig. 10 shows the mean follow-up time per BACTIP type. The TFUT for the series was 2,116 years. In type III the follow-up is recorded as zero as all cases underwent biopsy and surgical management shortly after the presenting scan. In the remaining types, the mean TFUT was 6 years 2 months. In types IA, IB, IIA, and IIB, the PFUT greatly exceeded the AFUT. In type IIC, the AFUT was almost double the PFUT reflecting the concerns regarding possible malignancy.

Ninety-seven (25%) patients underwent two or more MRI examinations allowing for assessment of any changes in length, endosteal scalloping, and development of aggressive features. In type IA, three patients showed increasing length on a follow-up scan. One increased from 1.2 to 1.8 mm (50%) over 9 years (Fig 2). A second, from 1.5

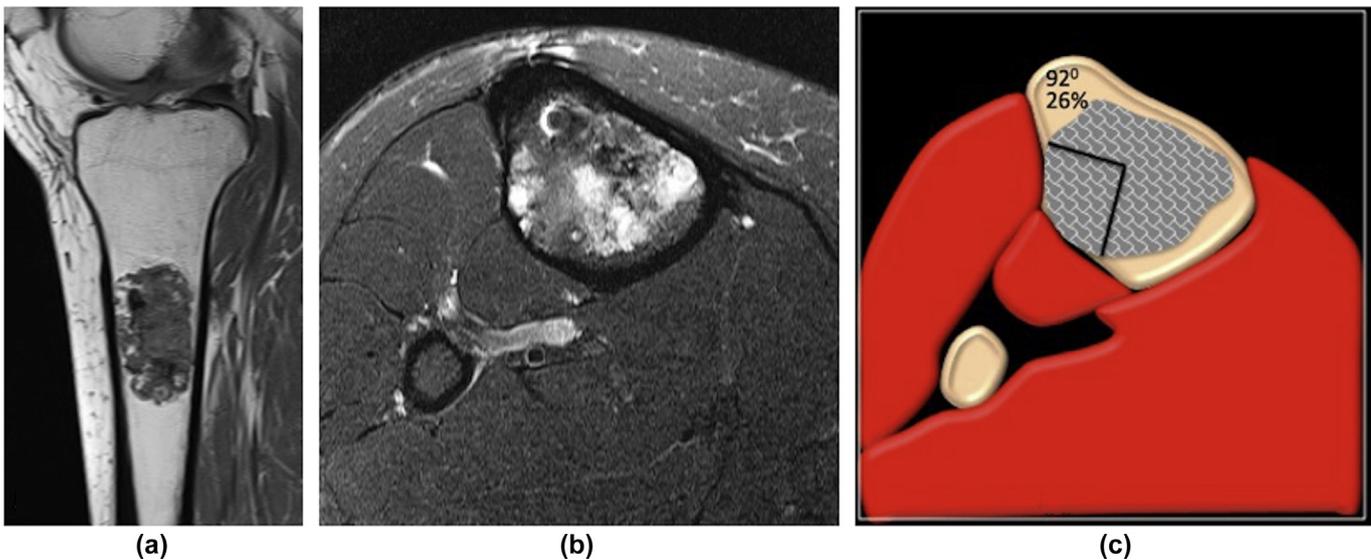


Figure 5 (a) Sagittal proton-density and (b) axial proton-density fat-saturated images with (c) transverse schematic. Type IIC CCT 4.2 cm in length with extensive (>36 deg) endosteal scalloping. Follow-up MRI 16-months later showed no interval change.

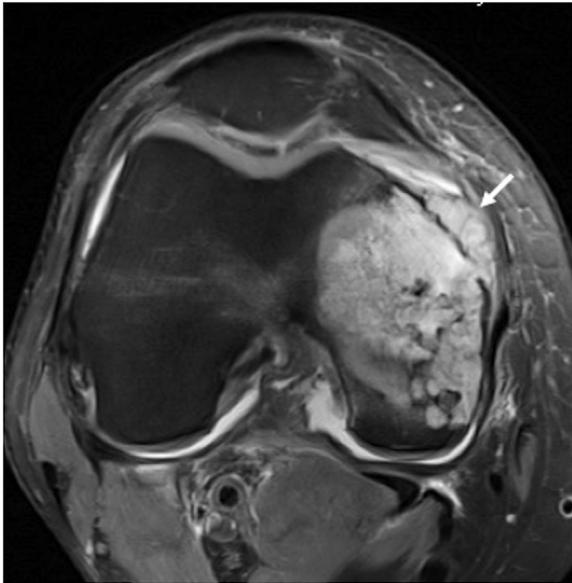


Figure 6 Axial proton-density fat-saturated image of a type III CCT with cortical destruction and soft-tissue extension anteromedially (white arrow). Biopsy showed dedifferentiated chondrosarcoma.

to 2.2 cm (38%) in 7 years, and the third 1.3–2.4 cm (85%) over 5 years 9 months. This last patient was lost to follow-up in 2012 and has not re-presented since. The increase in size only exceeded 1 cm in one of these three cases and all remained a type IA CCT. One type IB case increased in length from 1.6 to 2.2 cm (37%) in 3 years and remained a type IB CCT. One type IC case increased from 3.7 to 4.4 cm (19%) in 5 months that would have resulted in re-designating the case as type IIC; however, there was also evidence on the second scan of cortical destruction that automatically puts the case in the type III category. Biopsy revealed grade 3 chondrosarcoma.

One type IIA case showed an increase from 15.8 to 16.4 cm (4%) over 5 years 6 months. One type IIB case increased from 6 to 6.5 cm after 7 months, but was re-designated to type III due to soft-tissue extension. Biopsy showed grade 2 chondrosarcoma (Fig 4).

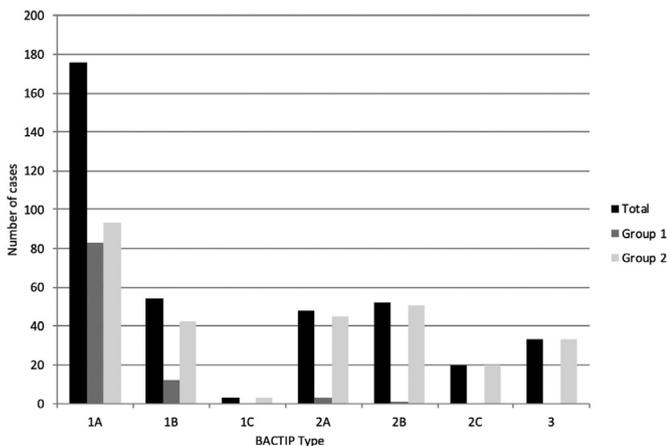


Figure 7 Number of cases per BACTIP type and group. Group 1 = primary or secondary and Group 2 = tertiary/oncology referral cases.

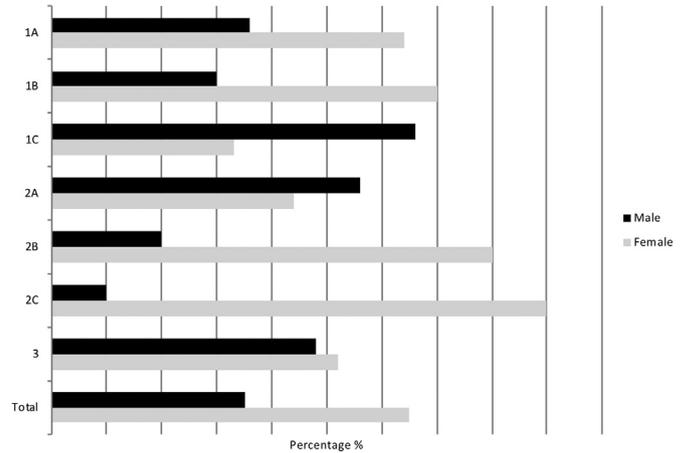


Figure 8 Sex distribution per BACTIP type.

Three type IIC cases showed an increase in length. One increased from 6 to 6.3 cm (5%) in 18 months, but remained unchanged when rescanned a year later. A second increased from 7.6 to 8.1 cm (7%) in 10 months, but a decision not to biopsy was taken on account of the patient’s advanced age. The third first presented in 2009 with a 4.9 cm CCT in the distal femur that needle biopsy showed to be an enchondroma. The patient was subsequently discharged only to represent almost exactly 10 years later with the CCT now 6 cm in length (22% increase), but still type IIC. This case remains under conservative review with follow-up MRI as the patient’s body mass index (BMI) rendered surgical management risky.

One type III case, already confirmed as chondrosarcoma on biopsy, showed an increase in length of 1.6 cm, from 8 to 9.6 cm (20%), 2 months later while awaiting surgery. Histology on the final resection confirmed dedifferentiated chondrosarcoma.

Overall, of the 94 cases, prior to biopsy, in which there was a follow-up MRI, 10 (11%) showed an increase in length with only two measuring >1 cm increase on the later scan. Eight remained the same BACTIP type with two (one type IC and one type IIB) re-classified to type III (Fig 4).

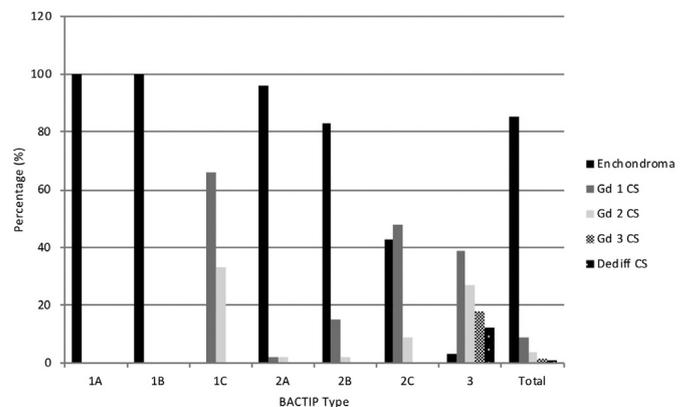


Figure 9 Percentage final diagnosis per BACTIP type.

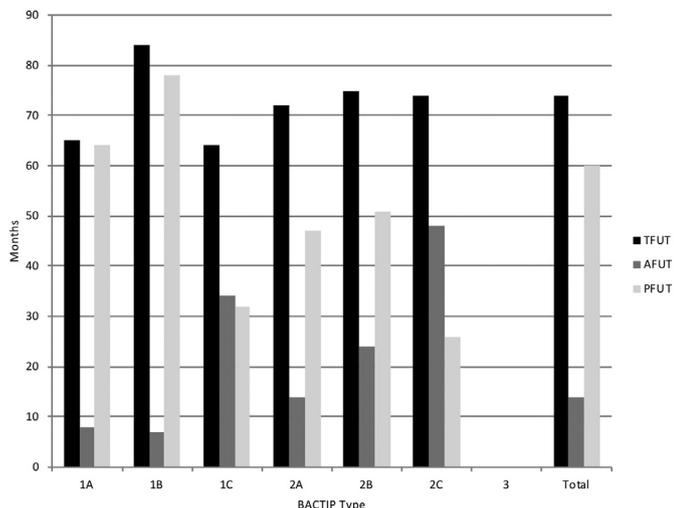


Figure 10 Mean follow-up (months) per BACTIP type. TFUT = total follow-up time. AFUT = actual follow-up time. PFUT = passive follow-up time.

Twenty-five cases were selected by the principal reviewer from the overall series to reflect a spectrum of BACTIP types. The remaining three authors each reviewed the 25 MRI examinations on two separate occasions and assigned a BACTIP type to each case. In 15 (60%) of the cases there was 100% inter- and intra-observer agreement as to the BACTIP type. These included all the type IA and 3 categories. In the remaining cases, the reviewers agreed with the principle reviewer in all 10 on one reading with a disagreement on the second reading. Discrepancies tended to be in those cases where the length of the CCT approximated to 4 cm or the angle of endosteal scalloping was close to 36°. Another contentious area was in the proximal humerus where deficiencies in scan quality often made it difficult to assess the presence/absence of endosteal scalloping with certainty.

Discussion

Specialist orthopaedic oncology units have experienced something of an epidemic of referrals of CCTs over recent years. In 2017, the unit at Royal Orthopaedic Hospital received 82 referrals for assessment of CCTs in the proximal humerus and around the knee equating to almost seven referrals per month.¹¹ This is hardly surprising as they are to be found in 3% of all routine knee^{25,26} and 2% of all shoulder MRI studies.²⁷ MRI is no longer considered a specialist investigation and patient expectations are such that it is now considered a first-line investigation for many musculoskeletal complaints. Indeed, this problem is only set to increase with the latest research in the use of tests in primary care in the UK, including over 250 million laboratory and imaging investigations, showing the highest overall average annual increase to be for MRI examinations of the knee.²⁸ It is for this reason that the present authors developed the BACTIP as a tool with which to assess those cases that require onward referral to a specialist orthopaedic

oncology unit and those which can be managed and where necessary followed-up locally.¹¹ The only change to the version of the BACTIP previously published in this journal is that the rare type IC (<1% of the series) should be considered a potentially aggressive lesion and therefore referred on to a specialist oncology service rather than be scheduled for follow-up MRI (Fig 1).

Previous studies conclude the need to differentiate “active”, corresponding to BACTIP types IC, IIC, and III, from “quiescent” CCTs advocating biopsy for the former with radiological follow-up for the latter to depict any interval change.^{16,29,30} It is the advice regarding the timing and duration of follow-up for the apparently non-aggressive CCTs that tends to be somewhat vague and at times would seem excessive. Muller and co-workers have suggested that radiographic follow-up would be sufficient for asymptomatic enchondromas³¹ but most these days would advocate MRI. Crim and co-workers recommend serial follow-up, presumably with MRI, but do not specify frequency.⁹ Sampath Kumar and co-workers recommend a surveillance MRI after 3 years.¹⁶ Parlier-Cuau and co-workers schedule the first imaging follow-up 3–6 months after initial evaluation and then, MRI preferred, once a year in the absence of any change.²⁹ Decker and co-workers recommend annual MRI, irrespective of the size of the CCT, for at least 2 years, and if unchanged, the frequency to be reduced to every 2–3 years.³² Herget and co-workers recommend annual or biannual MRI for asymptomatic CCTs >5 cm and biannual imaging with radiographs and, if any doubt, MRI for lesions <5 cm.³³ A recent review article advocates a MRI at 6–12 months after presentation with annual follow-up, usually with MRI.¹⁰

The rationale behind these recommendations is understandable particularly as these series, unlike the current study, include long bone sites where the likelihood of malignant change is known to be higher such as the proximal femur; however, the duration of follow-up is unclear with the time interval between the diagnosis of enchondroma and subsequent malignant transformation varying between 6 months and 30 years.⁴ Brien and co-workers recommend a follow-up of at least two decades if the CCT is detected after 25 years of age.¹ The literature quotes a malignant transformation rate of 2.5–6%.^{3,34,35} This would result, with a mean age of patient presentation in all types in the current study of 55–65 years, in lifelong surveillance of their CCT with at most a 1 in 20 chance of malignant transformation taking the highest estimated rate of change quoted in the literature. In the current series, with an average follow-up of just over 5 years, only two cases showed progression of the CCT and were shown to be chondrosarcomas (Fig 4). This gives a malignant transformation rate of <1% in this study with the remaining cases of malignancy diagnosed shortly after presentation and onward referral to the orthopaedic oncology service. It is for this reason that the BACTIP, rather than trying to predict the long-term biological behaviour of the CCT, attempts to identify those cases in which malignant transformation is already underway or at least imminent with MRI follow-up restricted to 1–4 years.

One of the most noteworthy results of this study is the clear female predilection for CCTs of almost 2 : 1 but 1 : 1 for chondrosarcoma (Fig 8). Older texts, prior to the routine use of MRI, indicate no sex predilection for enchondromas,^{36,37} but quote a male/female ratio for chondrosarcoma of 1.5 : 1.^{36,38} Whereas, Dahlin's authoritative textbook indicates a distinct female preponderance for enchondromas (60%) and a minor male preponderance for chondrosarcoma (57%).³⁹ This cannot be explained in the present study by population/sampling bias as, within the same time period in patients over the age of 40, our PACS has a records of 15,672 knee MRI examinations (51% male and 49% female) and 1,709 shoulder examinations (56% female and 44% male) archived. The lower total figure for shoulder MRI reflects that shoulder symptoms are less common than knee and that in the UK in middle aged and elderly patients ultrasound is often preferred to MRI. A similar female predominance has been recorded in several recent studies on CCTs, but the possible significance of this finding was not commented upon.^{9,16,32} If CCTs are almost twice as common in females then, if there is a direct relationship between CCTs and subsequent malignant transformation, one would expect to see a similar female predilection in chondrosarcomas. Another fact that might bring into question whether a direct causal relationship exists between CCT and chondrosarcoma can be extrapolated from the results of a recent study from the Netherlands.⁴⁰ This is a relatively small country with an internationally renowned centralised orthopaedic oncology service and a well-established Netherlands Cancer Registry. In this 2018 study, the authors noted the incidence of atypical cartilaginous tumour/grade 1 chondrosarcoma was increasing, suggesting this could be driven by both an ageing population and increased diagnostic imaging, particularly MRI. As a consequence the number of preventative curettages of these border-line tumours had increased but this had not, as yet, resulted in a decrease in the incidence of higher-grade chondrosarcomas presenting.

There are several potential criticisms/limitations of this study. A retrospective study, whereby historical patient data are applied to a new imaging protocol, is not as robust as testing the protocol in real time. The latter is not practical in this clinical scenario as it would take over a decade to collect adequate patient numbers and duration of follow-up to draw any valid conclusions. The follow-up of the patients in this study does not conform directly to the BACTIP. It does, however, encompass an adequate time period allowing for certain assumptions to be made regarding the possibility of disease progression thereby potentially revealing any weaknesses or flaws in the BACTIP (Fig 10).

The main reviewer was blinded to the final diagnosis when viewing the first MRI examination. Some subconscious bias was inevitable as on first opening the patient's imaging folder on PACS, it would be immediately obvious to the reviewer as to the nature and frequency of any follow-up studies. No follow-up studies would suggest a benign final diagnosis, whereas a listing of multiple further studies over time might prompt the reviewer to suspect a final diagnosis of malignancy.

The BACTIP is limited to the assessment of two MRI parameters: tumour length and presence/absence of endosteal scalloping. Previous publications have claimed other parameters can be helpful. For example, islands of fat within the main lesion⁴¹ and heavy calcification, best seen on computed tomography (CT),¹⁶ favour a benign diagnosis, whereas increasing symptoms^{5,14} and periostitis⁶ might suggest malignancy. Although the authors do not dispute these observations, they do feel that with a total of seven types (IA–III) already included in the BACTIP, the addition of further parameters would render the protocol cumbersome and reduce the likelihood of its acceptance/implementation on a wide scale. These other parameters could be taken into account in the minority of cases that, as a result of applying the BACTIP, are then referred on to a specialist orthopaedic oncology unit for further assessment.

There are issues with the definition of follow-up in this study (Fig 10). The AFUT includes all those with further imaging of the relevant anatomy. It does not distinguish between those undergoing the subsequent imaging to assess any change in the CCT from those in whom the indication for the later study was unrelated. In the latter situation the CCT happened to be in the field of view of the scan allowing assessment but this was not necessarily the reason why the repeat scan was undertaken. The PFUT assumes that if there was no further imaging on PACS then there had been no clinically significant disease progression. This seems a reasonable assumption as the current organisation and funding of tertiary supra-regional bone sarcoma services in England has led to a fairly stable pattern of patient referrals to each unit over the years. It would be most unusual for a patient originally referred to one unit to be referred elsewhere if disease progression was suspected unless the patient had moved out of the original specialist unit's catchment area. The PFUT may also be an overestimate in a small number of cases as it was not possible to identify which patients may have died in this period for entirely unrelated medical reasons with the oldest aged 90 years at initial presentation.

The BACTIP is only a tool to enable triaging of those cases where onward referral to a specialist orthopaedic oncology unit is most appropriate. It does not address how these patients, once under the care of a specialist unit, should be further investigated and which will require biopsy prior to a decision regarding surgical or non-surgical management.

There still remains the issue of the reference standard for diagnosis. The limitations of both imaging and histology in this respect are well recognised, such that in most specialist units, the final diagnosis relies on a consensus between the two achieved after discussion at a multidisciplinary team meeting/tumour board. The radiologists involved in this unit will have had an important input as to which cases were originally declared benign and which malignant with only a minority going onto biopsy (see [Electronic Supplementary Material](#)). Crim and co-workers have highlighted the difficulties in eliminating incorporation and consensus biases when performing a retrospective study such as this.⁹

Despite the reservations regarding this study expressed above, the authors feel that the BACTIP represents a safe and workable tool for the initial management of CCTs of the proximal humerus and around the knee (with the exception of the proximal fibula). If the BACTIP had been formally applied to the current series only a single case would have experienced a delay in diagnosis. A type IIB CCT changed to a type III on follow-up MRI 7-months later (Fig 4) and would not have been routinely scanned for a further 5 months. A type IC CCT also changed to a type III on follow-up 5 months later but the latest amendment to the BACTIP would have required this case to be referred on to a specialist orthopaedic oncology unit after the first examination.

A routine part of the initial assessment of any patient referred to our specialist service is to identify the likelihood of malignancy based on the initial imaging findings. The categories applied comprise “malignancy likely”, “malignancy possible”, “malignancy unlikely”, and “malignancy excluded,” which are then used to dictate timings and nature of further investigations including image-guided biopsy. Because of the perceived risk, albeit very small, of malignant transformation of CCTs, the “malignancy excluded” category was amended for those that appear benign according to the BACTIP to “malignancy excluded at this time”. This is in recognition of the fact that the BACTIP gives an assessment based on a single MRI examination or at most a follow-up over 1–4 years and cannot be used to predict what may or may not occur decades later. The hawkish observer might query, with a long-term malignant transformation rate of <1% in the present series, whether the follow-up advocated by the BACTIP is actually justified. It does constitute a reasonable risk-averse compromise whereby there is the perception of being seen to do something rather than the two extremes of either doing nothing or a never-ending cycle of annual/biannual MRI.

Conflict of interest

The authors declare no conflict of interest.

Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.crad.2019.08.017>.

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