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Comparing Rapid Spiral CT and Conventional X-ray for Reliable Detection of Peri-Prosthetic Osteolytic Lesions after Total Knee Replacement: Implications for Surgical Management

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KEYWORDS

Abstract

Increasing prevalence of osteolysis-induced mechanical failure has been shown in a number of longitudinal studies after total knee replacement (TKR). It can be difficult to accurately estimate osteolytic lesions prior to surgery, even with multiplane X-rays of high quality. A model that allows more reliable lesion assessment is Surgical management is likely to be affected significantly. A simulated cadaver model was used for this study in order to compare To conventional X-ray standards, spiral computed tomography (CT) is a rapid imaging procedure for the detection of osteolytic lesions in peri-prosthetic joints after TKR. The TKR implant components were located in three human cadaveric knees, nine volume-occupying defects were created to simulate osteolytic lesions. An X-ray series of two stages and a spiral CT were employed to image the knees after implant placement. The quality of CT images was improved using a beam-hardening artefact removal algorithm. A random image sorting procedure placed 12 radiologists in the same room and asked them to independent assess whether osteolytic lesions could be seen, what anatomic location they were located in, and their size. CT images were reviewed separately using the same process. To determine if osteolytic lesions are more easily detected on X-rays and CT scans, direct comparisons of the results were performed. In a study using just AP projections ($P = 0.008$), CT images significantly improved recognition accuracy ($P = 0.03$), as did biplanar oblique X-rays ($P = 0.005$). Based solely on APs and laterals, the introduction of oblique images did not improve the accuracy of identifying such lesions ($P = 0.13$). Conclusion: An imaging method based on CT scans that is simple and rapid method can be used to reliably describe peri-prosthetic osteolytic lesions non-invasively in this study. Even when supplemental bi-planar 45° oblique views are provided, conventional X-ray is low in sensitivity and therefore cannot be used in situ for screening TKR implants for osteolytic lesions. At routine orthopaedic follow-up, CT evaluation may be a better method for evaluating osteolysis around TKRs due to its ease of use and accessibility. As a result of these findings, surgical and non-operative management strategies are influenced by the It is important to detect such lesions early and to classify them accurately, as well as the nature and appropriateness of implants revisions and joint-salvage osteotomies.

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Introduction

Bony matrix instability around orthopedic implants is commonly caused by peri-prosthetic osteolytic lesions [1–5]. There have been several postulates put forward to explain this frequently observed phenomenon [1, 3, 6–8]. However, the exact mechanism remains unclear, and is currently being scrutinized internationally [9]. Osteolytic lesions must be recognized at their onset and progression. This appears to be universally accepted. So that appropriate management can be provided to the patient with the best possible result [8, 10], it is important to ascertain this at the earliest possible point. For such practices, it is essential to have a non-invasive technique that is both accurate and reliable for identifying lesions and describing their morphology.

Joint replacements are most commonly performed by total knee replacements (TKRs) in many countries [11]. There is a tendency TKR incidence is on the rise, according to extensive epidemiological data [9]. The expectation of maintaining mobility and physical activity is increasing in a The life expectancy of the population is increasing [7]. Various mechanisms may cause implant failure continues to pose a clinical problem [9], despite a majority of cases showing a Post-procedure standard of living improved and clinical outcome was positive [7]. It is well known that Loss of bone due to wear-induced particles (osteolysis) creates a mechanical instability and loosening of implants [8, 12]. As osteolysis progresses and reaches critical levels, it can lead to the failure of implants [10, 13, 14]. This has made peri-prosthetic osteolysis a significant clinical issue following TKR [8, 15]. In particular, patients who are young and active should undergo periodic radiographic surveillance after joint replacements [8, 16, 17]. By detecting problems early, management pathways can be enacted, and thus the patient's long-term outcome can be improved [8, 18, 19].

It is common practice to use plain film X-rays after surgery or to check the integrity and positioning of implants, In addition, adjacent bony regions should be evaluated [20–22]. CT scans are performed in a few institutions to augment plain film examinations or to replace them [10]. As a result, such practices are most often used on an individual basis with a secondary indication that is more pressing.

Multi-angle and multi-projection approaches have failed to be reliable for diagnosing osteolysis with plain film X-rays in the past [5, 21, 23]. Insufficient delineation of osteolytic margins has led to concerns regarding underestimation of lesion size within bone/implant interfaces [10, 18, 21, 23–25]. The lack of consistency and repeatability of successive (follow-up) examinations also limits the ability to compare them directly and thus the benefit of accurately monitoring progress [26]. Radiographic technique and patient positioning play a significant role in patient presentation (e.g. positioning of the patient, orientation of the Performing a projection series, determining the central beam, and superimposing images of structural images) [18, 21, 22, 27, 28]. Conventional CT scans have been criticized for poor alignment, even though they are often advocated [10, 28]. Therefore, volume estimates can be inaccurately extrapolated based on sectional images. As a result of beam hardening artefact, metallic objects in the scan field cause significant image distortion and can limit the clinical validity of images [5, 28, 30].

Total hip replacements (THR) are associated with osteolytic lesions [5, 32, 33] and the lesions appear to be relatively common [10]. Although such approaches appear to Superimposing images by performing a projection sequence, determining the central beam, and determining the focal point, there is little evidence of substantial application in the contemporary literature.

Studies are increasing in number demonstrating the feasibility of It may be possible to use CT-based peri-prosthetic bone assessments to provide a quick, technologically simple, accurate, and reliable method of assessing bone around TKRs method for estimating peri-prosthetic bone volume [5, 28, 30]. As CT scanners continue to advance, they have been able to reduce (or ameliorate) Hardening of beams caused by metal artefacts [5, 26, 31, 34], as well as A number of previously encountered pitfalls in orthopaedic imaging have been effectively overcome using software-based correction techniques [34]. An imaging technique that does not require invasive procedures, these technologies offer the potential to evaluate osteolysis in the region of the prosthesis [5, 14, 26, 30, 34].

An imaging technique based on CT that allows for rapid acquisition has been used to assess lesion recognition and description, as well as compare As an

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accurate description of peri-prosthetic osteolysis caused by TKR, this approach is superior to standard X-ray examination techniques is critical to clinical relevance. However, previous similar studies do not exist.

Materials and methods

The institutional ethics committee approved the ex vivo acquisition of three cadaver knee specimens. With the use of proprietary equipment and conventional surgical implant techniques, experienced orthopaedic surgeons inserted cementless tibial arthroplasty components in each specimen.

In situ Multipurpose CT scanners were used to image each knee, using conventional helical reconstruction (122.5kV, 250mA, 0.5 sec rotation, 16x0.5 mode SFOV 320 mm). As part of the acquisition process, a conventional beamhardening Filter for reducing 3D artefacts in Boost (dynamically). was used to reduce the amount of artefacts produced by the beam hardening process. A standard 4 x 6 sheet was used to film the CT data. Standard (clinical) radiographic imaging techniques (including plain film X-rays) were also used to obtain 45° AP-oblique paired projections, anteroposterior and lateral projections.

An implant component was removed post-imaging, then As described previously, this method is similar by Nadaud et al. (2003) [21, 34] and Claus et al. (2003) [8] were used to simulate osteolytic lesions by injecting The tibial implant components are adjacent to volumes of osteal defects. A standard acetabular reamer was used to create lesions. A low-density silicone filler was used to The density of nonosseous tissues is affected in the negative bone defects during imaging, thereby improving the Interface between air and bone formation. Repositioning the implants and closing soft-tissue overlays were performed Imaging was conducted under the same conditions as baseline imaging (t = 1). The knees were then scanned with plain film and As for the baseline CT scan (t = 1).

Afterwards, the same procedure was repeated twice (i.e. t = 2 and t = 3), resulting in ever-larger defect sizes. Data were collected prospectively and analyzed for osteolysis resulting Implant wear due to polyethylene at the host facility, which was observed clinically (unpublished data). Based on clinically observed osteolysis patterns (video), we estimated lesion sizes and anatomical distributions. After classifying the lesions into 'small', 'medium', and 'large', the data was further analyzed. We resulted in From nine osteal lesions in three knees, 36 imaging sets were obtained, including baseline images.

In order to maintain the anonymity of donors and track images, a four-digit number was assigned to each image or series of images. It was only the first two authors who received the code that linked the Information about the patient is identified by an identification number.

After completing a standard participant consent form, each observer received lateral and AP X-ray images at each time point (i.e. t = 0, t = 1, t = 2, and t = 3), It was determined whether or not each of the three knees demonstrated an osteolytic lesion peri-prosthetic and gave an approximate estimate of its size (mm3) for each set of images presented in random order to Six registrars, four advanced trainees, and two consultants comprise the 12 radiologists. Afterward, the observer was again Each AP/lateral image set must be paired with 45° oblique X-ray images for the diagnostic process to be repeated.

Observers were then shown spiral CT images for each of the four time points, for each of the three knees, arranged in an order that was random and unrelated to the method of evaluating plain X-ray films. There was no access to plain X-ray images (or previously recorded image assessments).

We made every effort to ensure uniform viewing conditions (i.e. ambient lighting, environmental noise levels). There was a random order for the presentation of knees or time points, with The images are viewed sequentially by each observer (in order to avoid presentation bias). Each session of image evaluation was attended by a member of the research team.

Statistical methods

To determine which imaging method provided the best accuracy of lesion identification, we computed paired t tests comparing A comparison of 45° AP-obliques and plain film X-rays alone with 45° AP-obliques and plain film X-rays and CTs. Based on the known sizes and locations of lesions as per surgery, accuracy is calculated as a percentage. StatView data analysis software was used for all statistical functions.

Results

Study-related image assessment was carried out by 12 independent observers. In order to calculate the mean volume for each size of lesion, Density of silicon and mass of lesion were taken into account (small 0.8 cm3, medium 2.6 cm3, large 10.5 cm3). AP/lateral X-rays alone were only 52.1% accurate in identifying osteolytic lesions across all volumes. When paired 45° AP-obliques were available, observer accuracy climbed to 56.3%, but rose to 71.5% when CT data were available.

The accuracy of identifying lesions and describing their size (small, medium, or large) were compared using paired t tests. An analysis of diagnostic accuracy revealed statistically significant differences between CT and AP and lateral X-rays (P = 0.03) and CT and AP and lateral X-rays (P = 0.08). A comparison of AP/lateral images alone with a combination of oblique X-rays did not show a significant advantage (P = 0.13). According to their size (small, medium, or large), additional analysis was performed on accuracy of diagnosis. In comparison to AP/lateral X-rays, CT was better for detecting 'large' lesions (P = 0.03), but neither AP/lateral images nor paired oblique images showed any difference in diagnostic accuracy (P = 0.34 or 0.06) when compared to paired oblique images. Lesions classified as 'medium' were analyzed using CT rather than AP/Lateral X-rays or (P = 0.02) Pair of oblique X-rays. In addition to standard AP/lateral projections, There was no difference between the oblique and paired X-rays (P > 0.99) over the addition of a single lateral X-ray. CT was once again superior to AP/lateral projections when compared to lesions deemed to be 'small' (P = 0.004). In contrast to the standard projection and paired oblique combinations, CT did not demonstrate any statistical significance (P = 0.78). An X-ray combination of an oblique and an AP/lateral showed superior results (P = 0.05) in identifying lesions that are small.

Discussion

A TKR lesion peri-prosthetic bony defect was identified using conventional spiral CT to determine its accuracy. A presurgical assessment of osteolytic lesions can be challenging even with multiplane X-rays of high quality. There is a reasonable argument that these findings will influence surgical management practices and provide a basis for developing an assessment model that is more accurate and reliable.

Compared with With CT images, radiologists evaluate osteolytic lesions around TKRs more accurately than with plain AP/lateral X-rays or with paired 45° oblique X-rays. We found that CT has a positive effect on cancer diagnosis may not be any more accurate at identifying small lesions than Two X-rays taken at the same time, one oblique, one AP/lateral when comparing lesions of different sizes. One could speculate that this result was obtained because of the small cohort size, which may have been too small to detect a statistically significant difference. Small lesions can be accurately identified with CT alone will need to be researched in the future, using a larger cohort of patients.

A pair of horizontal and oblique AP/lateral X-rays were not more effective in detecting large lesions when compared with CT. As the lesions are of substantial size, this may not come as a surprise, assuming the patient would become clinically symptomatic sooner rather than later.

A significant number of observers failed to support our study's results statistically the anecdotal belief that more experienced observers are more likely to recognize these lesions. Hence, comparing senior and junior radiologists' abilities to identify such lesions may be another potential future research topic. Although a general tertiary referral medical facility has a variety of clinical expertise, the observers employed here represent this range.

However, we acknowledge that, even though we attempted to reproduce as closely as The controlled cadaver model can be used to simulate possible in vivo conditions, there were some differences in Implant/bone interaction and tissue responsiveness following TKR versus post-TKR patients living today. Consequently, our model may show subtle differences in the appearance of osteolytic lesions. The controlled, highly reproducible environment of our study method, however, is suitable for preclinical research.

Additionally, clinically observed peri-prosthetic osteolytic lesions may not have been sufficiently represented by the homogeneous silicon, as imaging results suggest. This study was not designed Creating a clinically realistic image as it was a preliminary, preclinical study. Rather, it was designed to By an automated acquisition system, CT can be used for semi-quantitative osteolytic lesions to determine its value (or not). In vivo studies on active patients will be conducted in the future can be supported by the findings presented here.

The study also acknowledges that only osteolytic lesions were identified around the tibial A TKR component. Further research can be conducted through it if this premise can be extended to other implant types, such as curved femurs in TKRs.

It is possible to conclude from Discrete diagnoses comprising 432 records (27 lesions identified by 12 observers, plus 9 images without lesions) that findings have some external validity. However, Clinical trials to be conducted in the future are needed to determine whether In situ TKRs can be effectively screened with CT-based approaches.

Due to the widespread availability, relatively low cost, and ease of CT scanning for patients (i.e. no significant movement), as well as the ability to reformat the images directly or post-acquisition, we concluded that the use of plain X-rays for the examination of in situ TKRs in tertiary care settings is a more accurate alternative to the previously accepted method. According to our results, CT scanning is an effective method to diagnose osteolytic lesions around TKRs, especially where a high level of clinical suspicion exists for the development of those lesions.

Conclusion

In this study, we demonstrated that conventional spiral CT can accurately describe peri-prosthetic osteolytic lesions around TKRs in an in situ setting. We have also demonstrated that plain X-rays may not be the most appropriate imaging technique to diagnose osteolytic lesions associated with TKRs. In addition, we found that paired oblique X-rays were not helpful in diagnosing patients and risked excessive radiation exposure and effort by adding them to standard AP/lateral projections. As a result of these findings, Techniques for managing patients non-operatively and surgically may be influenced in terms of timing and aggressiveness, as well as Whether the planned implant is appropriate and what type it is revisions and osteotomies salvaged.

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