# RESEARCH



# Incidental findings in preoperative computed tomography images of robotic-assisted total joint replacement: a multi-center retrospective study

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# Abstract

**Background** The majority of robot-assisted total joint arthroplasties necessitate preoperative computed tomography (CT) scans. Incidental findings in these CT scans can introduce complexity into clinical treatment decisions. Consequently, this study sought to document the nature and frequency of incidental findings identified in preoperative CT imaging conducted for robot-assisted total joint arthroplasty, along with their impact on planned surgical procedures.

**Methods** This investigation constitutes a retrospective review encompassing patients who underwent primary robot-assisted total hip arthroplasty between January 2020 and January 2022 at the Second Affiliated Hospital of Xi'an Jiaotong University, the First Affiliated Hospital of Peking University, and Nanfang Hospital. It also includes patients who underwent robot-assisted total knee arthroplasty during the same period at the Second Affiliated Hospital of Xi'an Jiaotong University, the Third Affiliated Hospital of Peking University, Nanfang Hospital, and the Second Affiliated Hospital of Xi'an Jiaotong University, the Third Affiliated Hospital of Peking University, Nanfang Hospital, and the Second Affiliated Hospital of Zhejiang University. All CT examinations were initially interpreted by proficient musculoskeletal radiologists. Subsequently, the findings in the examination reports, whether significant or non-significant, were compiled and categorized.

**Results** A total of 218 patients, median age 63, were evaluated; 90 had incidental findings (41.3%), with 56 (25.7%) significant. Males were more likely to have findings (P=0.001). Nine needed additional imaging, and five required intervention.Our study highlights the impact of unexpected CT findings on surgical planning, which can delay or cancel surgeries and affect patient outcomes. It also urges surgeons to review medical histories and perform thorough examinations before surgery to prevent serious consequences.

**Conclusions** Radiologists often find incidental findings in preoperative CT scans for robot-assisted joint arthroplasty, with a 41.3% incidence rate. About 25.7% of these findings need physician follow-up, and under 5% require

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intervention, potentially causing delays or cancellations of procedures, while undetected findings could lead to fatal outcomes. Unexpected preoperative CT findings can enhance patient management and prevent complications, necessitating their inclusion in surgical protocols. Systematic assessment improves safety and outcomes, urging surgeons to review medical history and perform thorough examinations pre-surgery.

**Clinical trial registration** Clinical trial registration time: 19/05/2022, clinical trial registration number: ChiCTR2200060115.

Keywords Computed tomography scan, Incidental findings, Robotic-assisted, Total joint arthroplasty

## Background

Total joint arthroplasty (TJA) is considered the gold standard for the treatment of end-stage joint diseases, and can effectively relieve the pain of patients with joint diseases, improve the ability of joints to perform daily activities [1, 2]. The use of orthopedic computer navigation systems and surgical robots, which have been rapidly developed recently, can improve the accuracy and repeatability of surgical procedures. The robots can complete pre-operative surgical planning based on computed tomography (CT) data from joint images, including information such as bone amputation amount, prosthesis size and prosthesis installation position among others, which helps doctors make adjustments before and during surgery according to their own habits and patient-specific conditions [3–5].

CT scans acquired prior to robotic surgery usually reveal a variety of incidental findings, some of which are not related to the surgery, and some of which impact the surgery [6, 7]. Previous studies have demonstrated that such incidental findings are present across multiple disciplines such as oncology, emergency medicine, cardiology, respiratory medicine, and obstetrics and gynecology [8– 11]. For instance, Morakkabati-Spitz et al. analyzed the prevalence of incidental findings on breast magnetic resonance imaging (MRI) and found that 9% of the patients have a concomitant history of breast cancer and 81% of patients on preoperative staging had incidental findings. Additionally, extramammary findings found in these patients have a high probability to be malignant [11].

The implications from these incidental findings are two-fold: on one hand, meaningful incidental findings can enable doctors to timely adjust the diagnosis and treatment plan, providing high quality treatment to patients; On the other hand, meaningless incidental findings will increase patients' psychological burden on benign diseases and delay diagnosis and treatment planning [12, 13]. Additionally, failure to correctly manage incidental findings may jeopardize the patient's health [14, 15].

Although incidental findings in imaging studies such as computed tomography (CT) can pose challenges in clinical decision-making, it is essential to gain a deep understanding of these findings [16-18]. This reality

underscores the critical necessity of thoroughly understanding the implications of these incidental findings, particularly in the context of robot-assisted total joint arthroplasty (TJA) [6]. A comprehensive preoperative assessment, especially a thorough evaluation of incidental findings from advanced imaging technologies like CT, is crucial for effective surgical planning and patient care [19, 20]. These findings can profoundly influence the surgical approach taken and the overall management of the patient's condition, potentially altering the treatment process and affecting the patient's recovery trajectory [6, 21, 22].

Therefore, the purpose of this study is to determine the type and frequency of incidental findings detected on the preoperative CT scans for robotic-assisted TJA and evaluate their effect on the planned surgery.

Although preoperative computed tomography (CT) can reveal incidental findings that may affect surgical outcomes and postoperative recovery, the integration of CT incidental findings into the routine preoperative assessment for total joint replacement in the Chinese population has not been sufficiently explored. Our study will fill a critical gap in understanding the role of preoperative CT incidental findings in the planning and management of total joint replacement (TJR) under robotic assistance in the Chinese population. By analyzing incidental findings in CT examinations, physicians can conduct a more comprehensive assessment of patients, clarifying whether they can undergo surgery with robotic navigation and what specific treatments they may require, thereby better ensuring patient health. These incidental findings contribute to a deeper understanding of the patient's condition, allowing for the provision of more appropriate treatment plans.

#### Methods

Prior to the start of this study, institutional review board approval was granted. The experimental protocol was established, according to the ethical guidelines of the Helsinki Declaration and was approved by the Human Ethics Committee of the Xi'an Jiaotong University Second Affiliated Hospital. Written informed consent was obtained from individual or guardian participants. This was a multi-center retrospective cohort study of all patients who underwent robotic-arm-assisted primary total hip arthroplasty (THA) or total knee arthroplasty (TKA) between January 2020 and January 2022. The TKA data came from the following four medical institutions: the Second Affiliated Hospital of Xi'an Jiaotong University, the Third Affiliated Hospital of Peking University, Nanfang Hospital and the Second Affiliated Hospital of Zhejiang University. The THA data came from the following three medical institutions: the Second Affiliated Hospital of Xi'an Jiaotong University, the First Affiliated Hospital of Peking University and Nanfang Hospital.

This target population included all adult patients found by review of the radiology information system database who had a CT examination performed with an indication of pre-operative imaging for a robotic-assisted TKA or THA. Exclusion criteria included examinations that were a repeat of a pre-operative CT scan of the same extremity (i.e., technical scan errors) or examinations performed for indications other than pre-operative imaging for robotic-assisted arthroplasty. The search yielded 335 examinations performed between January 2020 and January 2022, while the final sample size included 218 examinations. Inclusion criteria include: (a) Adult patients; (b) Patients with indications for THA and TKA who are willing to undergo total joint replacement. Exclusion criteria include: (a) Presence of repeated scans of the same limb (technical scanning errors); (b) indications other than preoperative imaging for robot-assisted arthroplasty; (c) lost to follow-up.

All preoperative CT scans were examined by trained musculoskeletal radiologists at the time of initial imaging. Information about sex, age and incidental findings on the CT scan were obtained. Incidental findings were defined as any findings on a CT scan that were not connected to indications for THA or TKA. Therefore, findings such as osteoarthritis of the hip and knee joints, dysplasia of hip joint, osteonecrosis of the femoral head and degenerative joint changes were excluded from incidental finding classification, as they are included in the primary reasons for TJA. Significant incidental findings were defined as those that required follow-up with a physician.

Statistical analysis was performed using SPSS software (version 19.0). Student's t-test was used for numerical data following the normal distribution, and rank sum test was used for measurement data not following the normal distribution. ANOVA was used for categorical data. All P-values < 0.05 were considered significant.

# Results

A total of 218 patients with eligible CT images were evaluated (Fig. 1). Of the 218 CT exams, 88 (40.4%) were performed for THA and the remaining 130 (59.6%) were performed for TKA. Of the total CTs, 59.2% (N=129) were performed on females and 40.8% (N=89) on males.

The age range was 19–77 years with a median age of 63 years.

The initial search resulted in 90 (41.3%) patients with incidental findings. Incidental findings found in TKA patients were more than in THA patients and the difference was (63.3% vs. 36.7%, P=0.35). Additionally, the same statistically significant difference was detected between female and male patients (53.3% vs. 46.7%, P=0.002) (Table 1).

Further analysis of the incidental findings revealed that 25.7% (N=56) of CT scans contained significant findings that required follow-up by a physician (Table 2). A rate of 30.4% (N=17) of significant findings were found in the THA group versus 69.6% (N=39) in the TKA group (P=0.08). In addition, of the 56 scans with significant findings, most of them presented in males (58.9% vs. 41.1%, P=0.001). The most common finding in females was uterine fibroid (N=10) (Table 3), which was observed in 43.5% of female patients with incidental findings, and was also the most common finding in obstetrics and gynecology. Of these ten female patients, seven did nothing, two received further examination and only one eventually underwent hysteromyomectomy after further examination. The most common finding in males was prostatomegaly (N=21), which was observed in 63.6% of male patients with incidental findings, and was also most the common finding in genitourinary system. None of these twenty-one male patients examined the finding further. The patients with the following findings: teratoma (N=1) and lipomyoma in spatium intermusculare (N=1) received further examination but did not need procedural removal of the benign tumors. Pelvic neoplastic lesions (N=2), unspecified adnexal mass (N=1) and bladder tumor (N=1) received further examination and surgical excision. Overall, nine patients required supplementary imaging to better analyze their significant incidental finding including MRI of the tibiofibula, ultrasound and CT scan of the pelvis. Five patients required surgical intervention including pelvic tumor resection, hysteromyomectomy and bladder tumor excision.

# Discussion

This study retrospectively evaluated 218 preoperative CT examinations obtained for robotic-assisted THA and TKA, from a total of five different hospitals. The findings demonstrated that not only are incidental findings commonly identified on the pre-operative CT examinations (41.3%) but also many are significant incidental findings (25.7%). Ultimately, most patients do not require further imaging. However, some of the significant findings resulted in a delay or even cancelation of the planned surgery due to the discovery of alarming diagnoses, such as pelvic neoplastic lesions(N=2), unspecified adnexal mass (N=1) and bladder tumor(N=1). On the contrary, if and



Fig. 1 Flow chart of the study design

Table 1	Summarv	/ descriptives of	f incidental findings

	Patients without incidental findings N=128	Patients with incidental findings N=90	<i>P-</i> value
Sex			0.002*
Female	87(68.0%)	42(46.7%)	
Male	41(32.0%)	48(53.3%)	
Age	63(56,69)	64(54,71)	0.469
Arthroplasty			0.350
THA	55(43.0%)	33(36.7%)	
TKA	73(57.0%)	57(63.3%)	

underlying disease remains undetected, it may lead to further aggravation of the disease.

Robot-assisted TJA has been shown to increase the accuracy of prosthesis installation [23], improve the alignment [24], and optimize the homogeneity of the procedure [25]. However, there are accompanying problems

#### Table 2 Summary descriptives of significant findings

	Patients without significant findings N=162	Patients with significant findings <i>N</i> =56	<i>P</i> -value
Sex			0.001
Female	106(65.4%)	23(41.1%)	
Male	56(34.6%)	33(58.9%)	
Age	63(55,69)	64(57,72)	0.133
Arthroplasty			0.077
THA	71(43.8%)	17(30.4%)	
TKA	91(56.2%)	39(69.6%)	

that also require attention. In the present study, males were found to be more likely than females to have a significant incidental finding. At the same time, the incidence of prostatomegaly (N=21) accounted for 63.6% of the significant incidental findings in males, which was related to this. Compared with THA, TKA patients

Table 3 Breakdown of significant findings

Category	Finding
Gastrointestinal	Hepatic cyst( $n = 1$ )
Gynecological	Teratoma( $n = 1$ )
	Pelvic neoplastic lesions( $n=2$ )
	Uterine fibroid( $n = 10$ )
	Unspecified adnexal mass $(n=1)$
Genitourinary	Bladder tumor(n = 1)
	Prostatomegaly( $n = 21$ )
	Ureteral calculus( $n = 1$ )
Musculoskeletal	Kaschin-beck disease of the ankle $(n = 1)$
	Gonarthromeningitis $(n = 2)$
	Peripheral muscular atrophy of left or right thick $(n = 11)$
	l inomyoma in spatium intermusculare $(n = 1)$
	Popliteal cyst( $n = 1$ )
	Benign lesion of the lower left femur( $n=2$ )

require more significant incidental findings for physician follow-up (P=0.08), which is contradictory to the report of Tran et al. [7]. Nevertheless, this may be related to sample size and region.

In the 56 patients with significant incidental findings, only nine (4.1%) went on to further advanced imaging, in which five (2.2%) underwent surgical intervention. Although Hassebrock et al. suggested "significant additional costs" related to the unnecessary workup of incidental findings, the present study demonstrates that most significant incidental findings are managed without the need for any costly imaging. Of ten patients with uterine fibroid, only two received further examination and one eventually underwent hysteromyomectomy after further examination. Without these significant incidental findings, in the unlikely event that one of the fibroids became malignant or even metastasized, the outcome would be fatal and the cost would be much greater. The four patients who were diagnoses with tumors, namely pelvic neoplastic lesions (N=2), unspecified adnexal mass (N=1) and bladder tumor (N=1) had their tumors removed. Without these significant incidental findings, if they had already received TJA, their physical condition may not have been appropriate to be subjected to tumor removal, which would cause more damage.

To date, no studies have focused on incidental findings in preoperative CT scans of robot-assisted TJA in China. Due to the uneven development of medical care in China, some patients give little attention to health examinations, resulting higher proportion of incidental findings than that in foreign related studies. This high rate of incidental findings can also act as a reminder for Chinese joint surgeons, whether they prefer robot-assisted or conventional surgery, to carefully question their patients before surgery and conduct a general physical examination, otherwise it may lead to serious and unpredictable consequences.

The advantages of this study are as follows.First, it is a multicenter retrospective study covering 218 patients from five different hospitals, which makes our results more extensive and representative. Second, our study reveals a high incidence of unexpected findings (41.3%) in preoperative CT scans for robot-assisted total joint replacement, with 25.7% of these findings considered significant, providing important reference information for clinicians. Additionally, our study emphasizes how significant unexpected findings identified in preoperative CT scans can impact surgical planning, potentially leading to delays or cancellations of surgery, thereby affecting the overall treatment outcomes for patients. Finally, our study reminds surgeons to carefully inquire about patients' medical histories and conduct thorough physical examinations before surgery to avoid potential serious consequences.

There are limitations associated with this study. First, it is a retrospective review with a relatively small sample size. Second, the minimum patient follow-up was limited to one year, excluding any patients receiving treatment beyond this time frame. However, the advantage of this study is that it is a multi-center review, which can eliminate the influence of some regions. In future related research, we need to conduct larger-scale studies and extend the follow-up period to better understand the long-term impact of incidental findings on roboticassisted total joint replacement surgery in preoperative CT scans.

## Conclusions

Incidental findings are commonly detected by radiologists on pre-operative computed tomography (CT) imaging obtained for robotic-assisted joint replacement. When compared to females, males showed a higher incidence of both significant and non-significant incidental findings. About 25.7% of the incidental findings warranted physician follow-up, and less than 5% required subsequent procedural or imaging intervention. These findings suggest that considering the necessity of detection and management of associated incidental findings on pre-operative CT scans is crucial. Certain valuable findings can lead to the delay or even cancellation of total joint arthroplasty, and if undetected, the consequences could be fatal.

#### Abbreviations

- TJA Total Joint Arthroplasty
- TKA Total Knee Arthroplasty
- THA Total Hip Arthroplasty
- CT Computed Tomography
- MRI Magnetic Resonance Imaging

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#### Author contributions

LYT and TR designed the work, wrote and edited the main manuscript text, ZDQ and CRM were responsible for diagnosis of disease and analyzing the image data, LS and GX performed data and statistical analysis; WJ, YSG, CYP, TH, YP, LZY, and CY performed the radiographs and clinical data acquisition, WKZ and YP edited the manuscript. All authors reviewed the manuscript.

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#### Data availability

No datasets were generated or analysed during the current study.

### Declarations

#### Ethics approval and consent to participate

The experimental protocol was established, according to the ethical guidelines of the Helsinki Declaration and was approved by the Human Ethics Committee of the Xi'an Jiaotong University Second Affiliated Hospital. Written informed consent was obtained from individual or guardian participants.

#### **Consent for publication**

Written informed consent was obtained from the patient for publication of this study and any accompanying images.

#### **Competing interests**

The authors declare no competing interests.

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