Referral Patterns for Dual-Energy Computed Tomography in Diagnosis and Management of Gout: Ten-Year Experience at a Canadian Institution

Bo Gong, MSc\textsuperscript{a,}\textsuperscript{*}, Kamran Shojania, MD\textsuperscript{b,}\textsuperscript{c}, Faisal Khosa, MD, MBA\textsuperscript{a}, Savvas Nicolaou, MD\textsuperscript{a}

\textsuperscript{a}Department of Radiology, Vancouver General Hospital, Vancouver, British Columbia, Canada
\textsuperscript{b}Arthritis Research Canada, Vancouver, British Columbia, Canada
\textsuperscript{c}Department of Medicine, Division of Rheumatology, University of British Columbia, Vancouver, British Columbia, Canada

Abstract

\textbf{Purpose:} To analyze the utilization, indications, and outcomes of dual-energy computed tomography (DECT) gout imaging in clinical practice.

\textbf{Methods:} This retrospective study was ethics approved. Radiology reports of DECT gout scans between 2007 and 2016 were analyzed for trends of utilization, referral pattern, indication, and diagnosis.

\textbf{Results:} DECT gout referrals increased substantially (2007: 37; 2008: 72; 2016: 385; total: 1877). The largest number of referrals were from rheumatology (1160), emergency medicine (283), and family medicine (177). Most referrals (92\%) were requested to aid an initial diagnosis of gout. Other reasons included estimating the disease burden (6\%) or monitoring disease progression and effectiveness of treatment (2\%). Rheumatology accounted for most referrals for the latter two reasons (81\% and 97\%). Imaging findings of urate presence were similar in referrals from rheumatology (62\%), family medicine (62\%), and other medical specialties (62\%). The urate positive rates were slightly lower in referrals from emergency medicine (47\%) and surgical specialties (41\%). The most common differential diagnoses by referring specialties were calcium pyrophosphate dihydrate crystal deposition disease (CPPD) and other inflammatory or erosive arthritides (rheumatology, family medicine), CPPD and infections (other medical specialties), infections and fractures (emergency medicine, neoplasm and infections (surgical specialties).

\textbf{Conclusions:} The increasing utilization of DECT for gout imaging validates its clinical value. Varying clinical presentation could explain differences of urate positive rates among specialties. Our results support a multispecialty collaborative approach to the diagnosis and management of gout, with direct access to DECT gout imaging provided to various physician specialties.

Résumé

\textbf{Objet:} Analyser l’utilisation, les indications et les résultats des examens d’imagerie de la goutte par tomodensitométrie (TDM) en double énergie dans la pratique clinique.

\textbf{Méthodes:} Cette étude rétrospective a fait l’objet d’une approbation par un comité d’éthique. Les rapports des examens d’imagerie de la goutte par TDM en double énergie effectués de 2007 à 2016 ont été analysés pour déceler les tendances en matière d’utilisation, de demandes, d’indications et de diagnostic.

\textbf{Résultats:} Les demandes d’examen d’imagerie de la goutte par TDM en double énergie ont considérablement augmenté (37 en 2007, 72 en 2008 et 385 en 2016; total de 1 877). Les demandes provenaient majoritairement de services de rhumatologie (1 160), d’urgence (283) et de médecine familiale (177). La plupart d’entre elles (92 \%) visaient à confirmer un diagnostic initial de goutte. Les autres demandes d’examen ont été faites pour estimer le fardeau de la maladie (6 \%) ou vérifier l’évolution de la maladie et l’efficacité du traitement (2 \%). Pour ces deux derniers motifs, les demandes provenaient en majeure partie d’un service de rhumatologie (81 \% et 97 \% respectivement).
La proportion des résultats d’imagerie confirmant la présence d’urate était la même pour les demandes provenant d’un service de rhumatologie (62 %), de médecine familiale (62 %) et d’une spécialité médicale (autres, 62 %). Cette proportion était légèrement inférieure pour les demandes émises par un service d’urgentologie (47 %) et une spécialité chirurgicale (41 %). Les diagnostics différentiels les plus courants selon la spécialité étaient la chondrocalcinose articulaire (CCA) et autres formes d’arthrite inflammatoire ou érosive (rhumatologie et médecine familiale), CCA et infections (autres spécialités médicales), infections et fractures (urgentologie), néoplasmes et infections (spécialités chirurgicales).

Conclusions : L’utilisation accrue de la TDM en double énergie pour les examens d’imagerie de la goutte confirme la valeur clinique de cette technique. Les variations de l’évolution clinique pourraient expliquer les différences entre les spécialités quant aux taux d’examens confirmant la présence d’urate. Nos résultats appuient l’adoption d’une approche collaborative multidisciplinaire pour le diagnostic et la prise en charge de la goutte, avec accès direct à des examens d’imagerie par TDM en double énergie pour les différentes spécialités.

© 2018 Canadian Association of Radiologists. All rights reserved.

Key Words: Dual-energy computed tomography; Gout; Specialty; Utilization; Referral; Clinical practice

Gout is the most common inflammatory arthritis, affecting 1%-4% of population in the developed world [1]. It is caused by deposition of monosodium urate (MSU) crystals in joints or soft tissues, usually after prolonged periods of hyperuricemia [2]. Given the availability of urate lowering treatment, early diagnosis is critical to effectively manage gout [3], and to reduce the associated risk for renal and cardiovascular diseases [2].

Traditionally, the gold standard of gout diagnosis is microscopic visualization of negatively birefringent needle-shaped urate crystals in synovial fluid aspirated from affected joints [4]. But the clinical use of joint aspiration can be limited in many situations, for example, in morbid obesity, when joints are not easily accessible, when care providers lack the skills, or when patients decline the procedure [4,5].

Recently, dual-energy computed tomography (DECT) has received much attention for its potential as a rapid and noninvasive method of MSU detection and quantification in patients with gout [6]. Taking advantage of distinct attenuation patterns of elements under X-rays of two different energy levels, DECT has the ability to reliably differentiate certain materials, such as MSU [7]. Several studies have examined the clinical performance of DECT in the diagnosis of gout (showing sensitivities of 78%—100% and specificities of 79%—100%) [8–11], estimation of disease burden [8,12], and monitoring of effects of treatment [13]. As a result, the recently updated 2015 American College of Rheumatology/European League Against Rheumatism guidelines included DECT in the gout classification criteria [5].

Our aim was to map the role of DECT gout imaging in this multispecialty diagnostic and management approach.

Materials and Methods

Ethics Approval

The institutional ethics committee approved this retrospective study (H17-00061). The requirement for informed consent was waived because of its retrospective nature.

Data Collection

Our institution continues to offer DECT gout scans since 2007. Scans are performed using the SOMATOM Definition Flash Dual Source CT scanner with X-ray sources at both 80 and 140 kV energy levels (Siemens Healthcare).

The text of requisitions and radiology reports of all radiological examinations are stored in an online repository. To identify all DECT gout scans conducted from July 2007–December 2016, a data analysis specialist searched the online repository with the key words “gout OR urate OR uric acid AND dual-energy,” which returned 2135 scans.

Two board-certified, fellowship-trained radiologists with expertise in musculoskeletal imaging screened all 2135 requisitions and radiology reports. Our inclusion criteria were DECT scans of upper or lower extremities (hands, wrists, elbows, knees, ankles, or feet) conducted for the tentative diagnosis or management of gout, with the indication provided by the referring physician. DECT scans of the same patient on different body parts within the same day were considered a single event for our study. After the screening, 1877 DECT scans met our inclusion criteria and were included in the study.

Data Analysis

The requisition forms were analyzed to identify the referring physicians. The provincial physician directory hosted on the public website of the College of Physicians and Surgeons was used to determine the referring physician’s
specialty and practice location. The indication or history section of each scan was retrieved from the radiology report, and the purpose of the scan was categorized into groups (Table 1). Other information that was extracted and analyzed included year of the scan, patient sex, patient age at scan, the referring physician’s considered differential diagnosis, and whether urate deposition was detected according to the radiology report.

Regarding the urate positive rates and the distribution of the referring physician’s considered differential diagnosis, only scans requested for the reason of aiding an initial diagnosis were included in the calculation. Other analysis, such as the overall referral count, number of referring physicians, and patient demographics, included all 1877 DECT scans.

Statistics

Numeric results were represented by range, mean, and median. For statistical comparison of patient age in referrals from different specialty groups, Kruskal-Wallis one-way analysis of variance (ANOVA) on ranks was performed with Dunn’s Method for multiple comparisons vs the rheumatology group as control; \( P < .05 \) was considered statistically significant.

Results

A Rapidly Expanding Provincial Program

Within the 10-year study period from July 2007-December 2016, the yearly number of DECT gout scans increased dramatically (2007: 37 scans; 2008: 72 scans; 2016: 385 scans total: 1877 scans) (Figure 1). Two percent of the referrals were made by physicians located outside of the greater metropolitan area, with the farthest referral made by a physician 650 km from our institution.

Referring Specialties

We analyzed the distribution of referring specialties of the 1877 DECT gout scans included in our study (Table 2). The 3 major groups seeking these scans were rheumatologists (1160 scans, 62% of all scans), emergency physicians (283 scans, 15%), and family physicians (177 scans, 9%). The rest of the physician specialties were grouped into 2 large categories: medical and surgical specialties, which contributed 159 referrals (8%) and 73 referrals (4%), respectively. The “other practitioner” group included referrals made by nonphysicians (from nursing and podiatry) and those by referring physicians whose specialty could not be ascertained.

The number of referring physicians in each specialty group was also calculated. Although rheumatologists requested 62% of all referrals, the number of referring rheumatologists (50) only made up 15% of all referring physicians. The largest groups of referring physicians were from family medicine (97 physicians, 29%), other medical specialties (82 physicians, 25%), and emergency medicine (57 physicians, 17%). On average, each rheumatologist referred the most scans (23.2 scans per rheumatologist), a number much greater than other referring specialty groups. The next was emergency physicians (5.0 scans per emergency physician) (Table 2).

Among the rheumatology group, the referral count varied by each rheumatologist, with a range of 1-200 referrals in the past 10 years (average: 23.2, median: 11.5). Twenty-six rheumatologists referred at least 10 DECT gout scans, 14 referred at least 20, 11 referred at least 40, and 4 referred at least 80.

Over the past 10 years, there has been a steady increase of the number of referring physicians in all specialties groups (Figure 2). Initially, rheumatologists were the largest group of referring physicians (by the number of physicians who made referrals each year), with the physician count increasing rapidly between 2007 and 2010. In more recent years, emergency physicians and family physicians contributed most to the increase of the number of referring physicians.

Table 1

<table>
<thead>
<tr>
<th>Reason/referral count</th>
<th>Rheumatology</th>
<th>Emergency medicine</th>
<th>Family medicine</th>
<th>Medical specialties (other)</th>
<th>Surgical specialties</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial diagnosis</td>
<td>1028</td>
<td>278</td>
<td>169</td>
<td>152</td>
<td>69</td>
<td>1721</td>
</tr>
<tr>
<td>Estimate disease burden</td>
<td>98</td>
<td>5</td>
<td>7</td>
<td>7</td>
<td>4</td>
<td>121</td>
</tr>
<tr>
<td>Monitor progression/treatment</td>
<td>34</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>35</td>
</tr>
</tbody>
</table>

DECT = dual-energy computed tomography.

Figure 1. Number of dual-energy computed tomography (DECT) gout scans performed each year from 2007-2016.
Among all 1877 DECT scans, 70% of the scanned patients were men. The average age of patients at the time of scan was 61.4 (range: 14-99, median: 62). Using rheumatology referrals as control, the patient ages from emergency medicine, family medicine, and other medical specialties were statistically significantly higher, suggesting different patient populations from these specialty groups ($P < .05$, Kruskal-Wallis one-way ANOVA on ranks with Dunn’s Method for multiple comparisons) (Table 2).

### Patient Demographics

Among all 1877 DECT scans, 70% of the scanned patients were men. The average age of patients at the time of scan was 61.4 (range: 14-99, median: 62). Using rheumatology referrals as control, the patient ages from emergency medicine, family medicine, and other medical specialties were statistically significantly higher, suggesting different patient populations from these specialty groups ($P < .05$, Kruskal-Wallis one-way ANOVA on ranks with Dunn’s Method for multiple comparisons) (Table 2).

### Reasons for Referrals

The reasons for the 1877 DECT referrals were categorized into 3 groups: aiding an initial diagnosis of gout, estimating disease burden of existing gout, and monitoring disease progression or effectiveness of urate lowering treatment.

Most DECT gout scans were requested to aid an initial diagnosis of gout (1721 scans, 92%). Other scans were requested to estimate disease burden of existing gout (121 scans, 6%) or to monitor disease progress and treatment (35 scans, 2%). Referrals made for the latter 2 reasons were mostly from rheumatology (81% and 97%, respectively) (Table 1).

### Urate Positive Rates

DECT gout scans involve a minimal amount of radiation similar to traditional CT scans (2-3 mSv for all peripheral joints [8]) and can be more costly than other traditional diagnostic tools of gout. Thus, a request for DECT gout

---

**Table 2**

<table>
<thead>
<tr>
<th>Specialty group</th>
<th>Referral statistics</th>
<th>Patient demographics</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Number of referrals</td>
<td>Number of referring physicians</td>
</tr>
<tr>
<td>Rheumatology</td>
<td>1160</td>
<td>50</td>
</tr>
<tr>
<td>Emergency medicine</td>
<td>283</td>
<td>57</td>
</tr>
<tr>
<td>Family medicine</td>
<td>177</td>
<td>97</td>
</tr>
<tr>
<td>Medical specialties (Other)</td>
<td>159</td>
<td>82</td>
</tr>
<tr>
<td>Surgical specialties</td>
<td>73</td>
<td>35</td>
</tr>
<tr>
<td>Other practitioner</td>
<td>25</td>
<td>9</td>
</tr>
<tr>
<td>Total</td>
<td>1877</td>
<td>330</td>
</tr>
</tbody>
</table>

Patient ages at scan are expressed as mean ± SEM.

DECT = dual-energy computed tomography; SEM = standard error of the mean.

* Denotes $P < .05$ vs rheumatology referrals as control (Kruskal-Wallis one-way analysis of variance on ranks with Dunn’s Method for multiple comparisons).
imaging warrants judicious use in appropriate clinical scenarios.

We compared, among different referring specialties, the urate positive rate (used as a surrogate indicator of the appropriateness of DECT gout referrals). Past research has shown a discrepancy of knowledge levels of gout diagnosis and management among different physician specialties [14,15]. However, in our study, the urate positive rates were largely comparable among different referring specialty groups. Rheumatology (62%), family medicine (62%), and other medical specialties (62%) had similar urate positive rates. Slightly lower were the urate positive rates in referrals from emergency medicine (47%) and surgical specialties (41%) (Table 3).

Among rheumatologists, the urate positive rates also varied. There were 26 rheumatologists who requested at least 10 DECT gout scans for the purpose of aiding an initial diagnosis of gout. Their urate positive rates were found to range from 36%—95% (average: 67%, median: 69%). A distribution of these rheumatology urate positive rates is plotted in Figure 3.

Physicians of different specialties potentially encounter gout cases in different clinical scenarios, with varied symptoms and history. We investigated whether differences existed in the differential diagnoses of referrals made by physicians from different specialty groups.

Among 1721 referrals made for the reason of aiding an initial diagnosis of gout, 527 referrals (31%) provided differential diagnoses. These differential diagnoses could be categorized into the following 6 main groups: CPPD disease; other erosive or inflammatory arthritides (including rheumatoid arthritis, psoriatic arthritis, erosive osteoarthritis, etc.); infections (including septic arthritis, osteomyelitis, cellulitis, etc.); fractures; neoplasm (such as sarcoma); and others. As shown in Figure 4, there were indeed wide differences in the common differential diagnoses of referrals from different physician specialties. Such differences may explain the differences in urate positive rates between these specialty groups.

Discussion

The novelty of our study lies in the exploration of routine clinical practice of utilizing DECT gout imaging. While previous research focused on the clinical performance (such as sensitivity and specificity) of DECT in the diagnosis of gout, our study is the first to link the performance with actual popularity in routine clinical practice and thus provide further validation of the clinical value of DECT gout imaging. Our results suggest that different specialties encounter unique patient populations and disease presentations. They may explain the differences in the urate positive rates and support the notion of providing direct access of DECT gout imaging to various physician specialties.

The concept of DECT was proposed in 1979, but because of technical limitations, it only became practical to be used in clinical settings after the availability of commercial scanners in 2005 and 2006 [6]. Our results show a rapid increase in the utilization of DECT gout imaging from all physician specialty groups, with the largest increase in the number of referring physicians from emergency medicine and family medicine. We identified the reasons of the DECT gout imaging referrals, showing that most referrals were made to aid an initial diagnosis of gout. Other referrals were made for estimating disease burden of existing gout or monitoring disease progression and treatment, with the majority of referrals made for these 2 reasons from rheumatology. We also calculated the urate positive rates in referrals from different specialty groups and proposed that the differences in urate positive rates could be explained by different clinical presentations seen in different specialties, as illustrated by the differences in common differential diagnoses of gout cases.

The number of referring physicians from emergency medicine and family medicine increased the most in recent years. This is consistent with their important roles in the
diagnosis and management of gout. Previous research showed that a large proportion of gout cases, especially during acute phases, were managed in primary and acute care settings [5,15–17]. In our results, the referrals from these 2 specialties, when combined, accounted for 25% of all referrals, much less than the percentage of rheumatology referrals (62%). Therefore, we expect there will be continuing growth in referrals from these 2 specialties.

Although previous research showed potential discrepancy of knowledge level of gout management between primary care physicians and rheumatologists [14], our results showed the same urate positive rates in referrals from family medicine and rheumatology. Given the large number of gout cases encountered by family physicians and the much smaller average referral count per family physician, it is possible that family physicians only referred more severe gout cases with a high pretest probability.

Our results also showed slightly lower urate positive rates in referrals from emergency medicine and surgical specialties. We proposed that the unique clinical presentations, as suggested by differences in common differential diagnosis, could explain these slightly lower urate positive rates. For example, infections and fractures were the most common differentials in emergency medicine referrals. Requesting DECT gout imaging for such scenarios, even if resulting in a slightly lower urate positive rate, in our opinion, is still justified. In fact, these examples highlight the ability of DECT to definitively confirm urate deposition in tissues and thus differentiate gout from a large number of comorbidities, which is often difficult to achieve with other diagnostic modalities. Furthermore, in case of fractures, DECT can also help with the diagnosis by detecting any associated bone marrow edema.

Even among rheumatologists, the urate positive rates varied. The variation in urate positive rates could be explained by 2 reasons. First, the smaller the referral count of an individual rheumatologist, the bigger the statistical fluctuation in the urate positive rates. Second, the different urate positive rates also could indicate different practice patterns and patient populations among rheumatologists.

**Limitations**

Our study has its share of limitations, mostly because of its retrospective nature. In many requisitions, we wished more information could be provided by the referring physician to allow us to more finely differentiate the reason of the DECT scan request. There are several questions we would like to ask. First, was an aspiration done, and if no, why (was that because of joints in difficult-to-access locations, lack of physician skills, or patients in inter-critical period)? Second, calculating the urate positive rate, we only differentiated the presence or absence of urate deposition, without taking into consideration the severity and location of the deposition. If we had more comprehensive prescan background information, the severity and location of the urate deposition could provide important information about the consistency between the physician’s diagnostic suspicion and the actual DECT results. Future prospective studies should answer questions in these 2 aspects.
Conclusion

We completed a novel study to highlight the trends of utilization, indications, and outcomes of DECT gout imaging in routine clinical practice, using a comparison of referring physician specialty groups. The steady increase in the utilization of DECT validates its clinical value in the diagnosis and management of gout. The comparable urate positive rates among different referring specialties, combined with diverse patient populations and clinical presentations, support the notion of providing direct access of DECT gout imaging to various physician specialties.

Disclosures

The Department of Radiology, Vancouver General Hospital has a Master Research Agreement with Siemens Healthcare, Forcheim, Germany. Dr Khosa is the recipient of the Canadian Association of Radiologists/Canadian Radiological Foundation Leadership Scholarship (2017).

References