J of Nuclear Medicine Technology, first published online April 5, 2021 as doi:10.2967/jnmt.120.261552

U.S. Diagnostic Reference Levels and Achievable Administered Activities for Adult Renal Scintigraphy: An Analysis of the Intersocietal Accreditation Committee Nuclear Laboratories

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Word Count:2148

Short Title/Running Head: U.S. Adult Renal Scintigraphy DRL and AAA

ABSTRACT

PURPOSE:

The goal of this work was to determine U.S. diagnostic reference levels (DRLs) and achievable administered activities (AAAs) for adult renal scintigraphy.

MATERIAL and METHODS:

Under an Institutional Review Board approved protocol, data were collected from the Intersocietal Accreditation Commission (IAC) during one three-year accreditation cycle encompassing 110 facilities. Elements included radiopharmaceutical, administered activity, practice type, and examination volume. DRLs and AAAs were calculated and compared to non-US values and societal recommendations as available.

RESULTS:

93 facilities provided data on to 99mTc mercaptuacetyltriglycine (MAG3) and 15 provided data on 99mTc diethylenetriaminepentaacetic acid (DTPA) for adult renal scintigraphy exams. Analysis demonstrated a DRL of 392.2 MBq (10.6 mCi) for MAG3 and 531.7 MBq (14.4 mCi) for DTPA, with an AAA of 370 MBq (10 mCi) for MAG3 and 445.9 MBq (12.1 mCi) for DTPA.

CONCLUSIONS:

The resultant calculated novel US DRLs and AAAs may serve as benchmarks that nuclear medicine facilities may use to refine renal scintigraphy protocols, reduce patient doses and potentially guide future societal guideline recommendations.

KEY WORDS: reference levels, renal scintigraphy, administered activity, MAG3, DTPA

INTRODUCTION

Given the potential for radiation-induced cancers and other health issues, it is the responsibility of imaging providers to tailor exams using ionizing radiation such that a diagnostic study is achieved with the lowest amount of radiation dose imparted to the patient. In nuclear medicine, the radiation dose is proportional to the administered radiopharmaceutical activity, and hence it is essential that the minimum activity necessary is utilized that will provide for acceptable diagnostic quality.

Two metrics that have been identified to aid in this effort are the diagnostic reference level (DRL) and the achievable administered activity (AAA). The DRL, as defined by the International Commission on Radiological Protection (ICRP), is the 75th percentile of dose associated with a diagnostic imaging study, while the AAA is defined as the 50th percentile (median) (*1*). In the field of nuclear medicine and molecular imaging, given the relationship between radiation exposure and administered activity of the specific radiopharmaceuticals, these values are expressed in megabecquerels (MBq) or millicuries (mCi). The percentiles, and hence the underlying activities, are derived by surveying imaging facilities using various standard techniques and technologies.

Three surveys to date have identified the DRLs and AAAs for many U.S. nuclear medicine examinations, including myocardial perfusion imaging, planar and SPECT bone scintigraphy, hepatobiliary scintigraphy, lung perfusion scintigraphy, I-123 and I-131 thyroid exams, brain and whole-body F-18 FDG PET/CT, and F-18 amyloid brain PET/CT (*2,3,4*). One of the less common nuclear medicine procedures, renal

scintigraphy, can impart a moderate dose of 2.59 mSv when administering the standard adult radioactivity but does not have the benefit of well-established DRLs and AAAs. The only prior U.S. data is derived from a small survey with only 9 respondents and is limited MAG3 and no data pertaining to DTPA (*5*). The aim of this study was to accurately determine these values for U.S. nuclear medicine facilities for adult renal scintigraphy based upon accreditation surveys and add this to the growing body of nuclear medicine reference levels so that facilities may use them to optimize protocols and potentially guide future societal guideline recommendations.

MATERIALS and METHODS

Under an Institutional Review Board approved protocol with the requirement to obtain informed consent waived, de-identified data regarding administered activities for adult renal scintigraphy were collected from the Intersocietal Accreditation Commission (IAC) nuclear medicine accreditation program during one three-year accreditation cycle from October 2015 through December 2018. The accreditation process requires nuclear laboratories to submit demographic and practice data. For each area the facility is seeking accreditation (e.g., lung, hepatobiliary, brain scintigraphy; oncologic PET/CT), they submit two example examinations along with information regarding the radiopharmaceutical used, the administered activities, and final reports along with the standard operating procedure or protocol. For genitourinary nuclear medicine accreditation, the facilities may choose to submit material from adult and or pediatric examinations, and these may include any combination of diuretic renography, ACE-inhibitor renography, or renal cortical imaging exams. The cycle included 110 facilities

applying for genitourinary nuclear medicine scintigraphy accreditation. Two provided only information regarding pediatric renal scintigraphy, and thus 108 sites information was included in the final data set. Facility demographics showed a majority of sites were hospital-based (n=74), and approximately one-third were out-patient imaging centers (n=34) with a wide range in volumes for both general nuclear medicine studies and genitourinary scintigraphy studies (TABLE 1).

RESULTS

The majority of facilities use 99mTc MAG3 based protocols; a small minority used 99mTc DTPA, and a few used both. This resulted in MAG3 dose data being provided by 93 facilities and DTPA dose data from 15 facilities with 182 MAG3 and 24 DTPA adult administered activities available for assessment. Additionally, there was 1 report using 99mTc DMSA, and 1 using 99mTc Glucoheptonate included in submissions and discarded from the analysis. Two submitted adult diuretic renal scintigraphy reports failed to note the dose and were also excluded as well as 10 excluded pediatric patient reports. Minimum, average, maximum administered activities were determined, and DRLs along with AAAs were tabulated (TABLE 2) for analysis and comparison to DRLs and AAAs of non-US facilities as available.

DISCUSSION

The priority for any imaging study is to achieve the diagnostic quality necessary to answer the clinical question. In the setting of exams using ionizing radiation, this must be carefully balanced with the patient radiation dose. In the absence of empiric experimental

data, survey data and the resultant determined reference levels may be employed to guide practitioners and professional societies. DRLs, indicating the 75th percentile for administered activities for a specific nuclear medicine procedure and radiopharmaceutical can indicate if the amount administered is unusually high and are viewed as the first step in optimizing patient dose (*6*). Facilities routinely exceeding the DRL may benefit from reviewing their technique to determine if exams may be performed using a lower administered activity while maintaining adequate diagnostic quality. In contrast, the AAA, indicating the 50^{th} percentile, is considered a goal for nuclear laboratories to strive for with prescribed administered activities. The overarching objective of both these metrics is to aid facilities in avoiding unnecessary patient radiation dose.

Several high-quality surveys of U.S. nuclear medicine facilities have identified the DRLs and AAAs for many radiopharmaceuticals and studies; however, renal scintigraphy was either not reviewed or yielded too few data points to provide accurate values until now (*2,3,4*). Analysis of survey results from IAC accreditation data revealed a US DRL of 392.2 MBq (10.6 mCi) for MAG3 and a minimally less AAA of 370 MBq (10 mCi), with nearly a third of values falling between these two values and another third being within 37 MBq (1 mCi) of either side of this range, indicating a narrow band of administered activities across the majority of sites (FIGURE 1). The same analysis revealed slightly greater values for DTPA with a US DRL of 531.69 MBq (14.4 mCi) and an AAA of 445.85 MBq (12.1 mCi) (FIGURE 2).

Such values are available for Japan and much of Europe, providing an opportunity to compare and contrast with the IAC survey results. DRLs for Japan are 399.6 MBq (10.8 mCi) for both MAG3 and DTPA (7). In contrast, European researchers found a much lower MAG3 DRL of 99.9 MBq (2.7 mCi) to be the most common value reported from its survey of 36 countries, with the individual country DRLs ranging from 99.9-370 MBq (2.7-10 mCi) (*8*). The majority of the US MAG3 administered activities fell below Japan's DRL, but all exceeded the European DRL. In contrast, the majority of US DTPA administered activities exceeded Japan's DRL (FIGURE 3).

The ACR-SPR practice parameter for renal scintigraphy allows for adult doses up to 370 MBq (10 mCi) for MAG3 and 555 MBq (15 mCi) for DTPA (*9*). In contrast, while the SNMMI-EANM procedure standard allows for doses up to 370 MBq (10 mCi) for both agents, it recommends lower administered activities of 37-185 MBq (1-5 mCi) for most applications (*10*)]. This lower range is supported by at least one study, which showed no increased interpretation benefit or relative function determination accuracy when comparing doses of 300-370 MBq (8.1-10 mCi) to 37-185 MBq (1-5 mCi) (*11*). The IAC survey analysis shows that administered activities in the U.S. generally show consistency across facilities at the upper range of the values endorsed by societal parameters and guidelines, with only a small portion of facilities utilizing MAG3 administered activities well below both the DRL and AAA.

CONCLUSION

This practice-based survey of administered activities used by a large number of U.S. nuclear laboratories for the performance of adult dynamic renal scintigraphy has resulted in the first valid national reference levels for this nuclear medicine exam. Resultant DRLs of 392.2 MBq (10.6 mCi) for MAG3 and 531.7 MBq (14.4 mCi) for DTPA, with AAAs of 370 MBq (10 mCi) for MAG3 and 445.9 MBq (12.1 mCi) for DTPA were identified. These values may serve as benchmarks that nuclear medicine facilities may use to refine their renal scintigraphy protocols as well as guide future societal recommendations and organizational accreditation processes. Given that reference level values are dependent on the state of practice and the available technology at a particular point in time, future downward evolution of these values is likely based upon improvements in equipment, techniques, and expertise.

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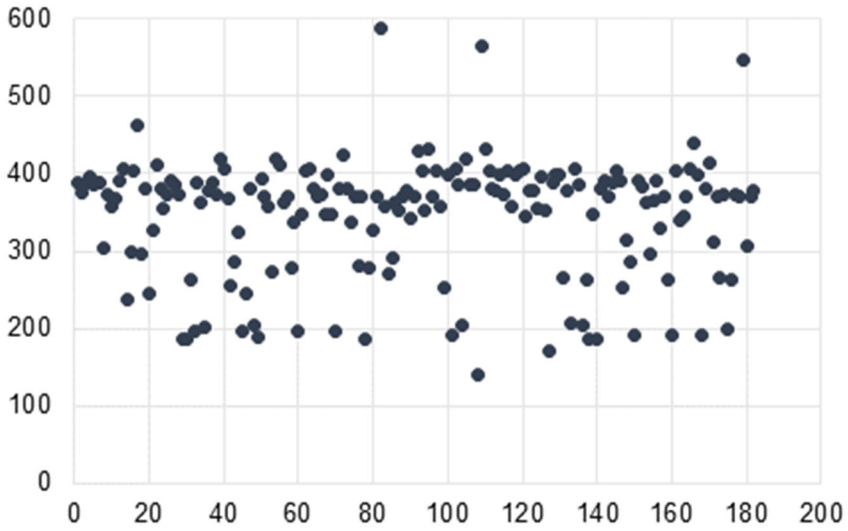

FIGURE 1: Distribution of 182 99mTc MAG3 administered doses. Vertical axis is activity in MBq. Vast majority of values are close to 370 MBq (10 mCi).

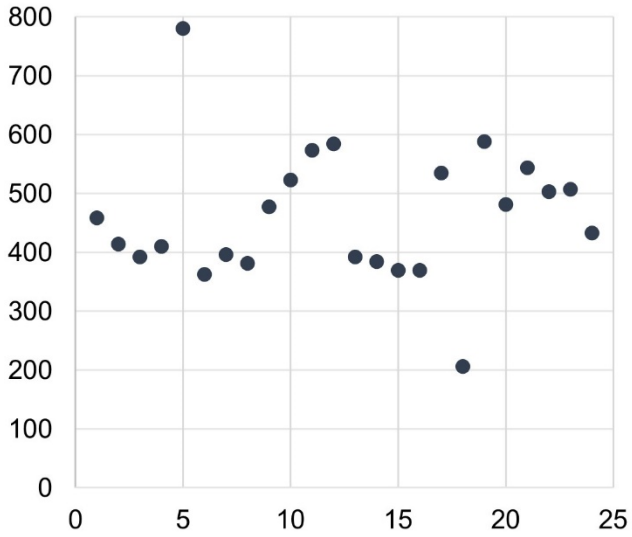

FIGURE 2: Distribution of 24 99mTc DTPA administered doses. Y axis is activity in MBq. Nearly all fall within 370-555 MBq (10-15 mCi) range.

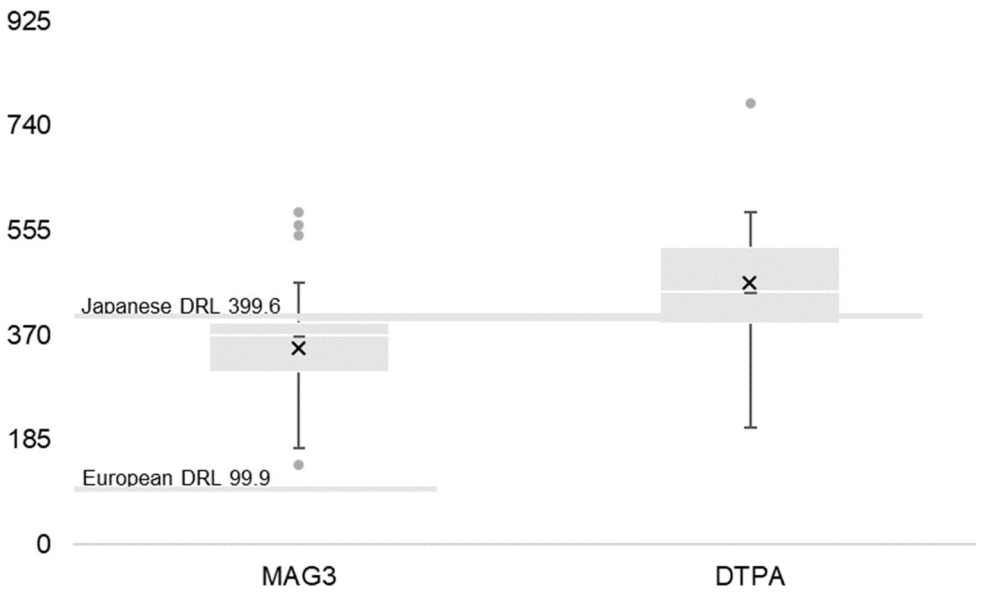

FIGURE 3: Box and whisker plot comparing minimum, maximum, and quartiles for US MAG3 and DTPA administered activities in MBq along with outliers versus DRLs from Japan and Europe (MAG3 only).

TABLE 1: Practice characteristics of the 108 facilities included in IAC accreditation survey period of Oct 2015 - Dec 2018.

FACILITY CHARACTERISTICS	Ave	Max	Min
# Gen Nuclear Exams per Year	1763	9076	95
# GU NM Exams per Year	86	697	3
% GU NM of Practice	5%	37%	0.50%

IAC = Intersocietal Accreditation Commission, Gen Nuclear = all non-PET, non-MPS diagnostic exams, GU = genitourinary, NM = nuclear medicine

TABLE 2: Analysis of administered activities by radiopharmaceutical.

MBq (mCi)	MAG3 (n=182)	DTPA (n=24)
MIN	140.6 (3.8)	206.1 (5.6)
25th percentile	303.4 (8.2)	386.7 (10.5)
50th percentile (AAA)	370 (10)	445.9 (12.1)
75th percentile (DRL)	392.2 (10.6)	531.7 (14.4)
MAX	588.3 (15.9)	780.7 (21.1)

Graphical Abstract