Incidence of Nephrogenic Systemic Fibrosis after Adoption of Restrictive Gadolinium-based Contrast Agent Guidelines

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**Purpose:** To retrospectively determine the incidence of nephrogenic systemic fibrosis (NSF) in a large academic medical center after the adoption of restrictive gadolinium-based contrast agent (GBCA) administration guidelines.

**Materials and Methods:**
For this retrospective HIPAA-compliant study, institutional review board approval was obtained and the requirement for informed consent was waived. Restrictive GBCA guidelines were adopted in May 2007. The guidelines require a recent serum creatinine level measurement in any patient who is aged 60 years or older and/or at risk for renal disease, (b) limit the maximal weight-based GBCA dose administered to any patient with an estimated glomerular filtration rate (eGFR) lower than 60 mL/min/m² to 20 mL, and (c) prohibit the administration of any GBCA in patients who have an eGFR lower than 30 mL/min/m² and/or are undergoing chronic dialysis treatment (except in emergency situations). The electronic medical records were searched for all contrast material–enhanced magnetic resonance (MR) imaging examinations performed during the post–guidelines adoption period between January 2008 and March 2010 and the pre–guidelines adoption and transitional period between January 2002 and December 2007. Separate pathology records were searched for biopsy-confirmed cases of NSF during the same study periods. The incidences of NSF during the pre–guidelines adoption and transitional period and post–guidelines adoption period were compared by using the paired Z test.

**Results:** A total of 52,954 contrast-enhanced MR examinations were performed during the post–guidelines adoption period. Of these 52,954 examinations, 46,464 (88%) were performed in adult patients with an eGFR of 60 mL/min/m² or higher or presumed normal renal function and 6,454 (12%) were performed in patients with an eGFR of 30–59 mL/min/m². Thirty-six patients with an eGFR lower than 30 mL/min/m² underwent contrast-enhanced MR imaging for emergent indications. Review of the pathology records for January 2008 to September 2010 revealed no new cases of NSF resulting from GBCA exposure.

**Conclusion:** After restrictive guidelines regarding GBCA administration were instituted, no new cases of NSF were identified among 52,954 contrast-enhanced MR examinations, including those performed in patients with an eGFR lower than 60 mL/min/m².

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Nephrogenic systemic fibrosis (NSF), previously known as nephrogenic fibrosing dermopathy, is a well-recognized but poorly understood syndrome characterized by progressive multiple-organ fibrosis. To our knowledge, the cutaneous manifestations, including hyperpigmentation and brawny induration of the skin, were first observed in 1997 but were not reported until 2000 (1–4). A multiplicity of extracutaneous systemic manifestations, including visceral organ fibrosis and vascular thrombosis, has since been recognized (5–8) and described. NSF appears to occur exclusively in patients with renal impairment, and to our knowledge, no cases to date have been described in a patient with normal renal function. The association between NSF and gadolinium-based contrast agents (GBCAs) was first proposed in a 2006 study in which the investigators reported that five of nine patients with pathologically proven NSF had undergone contrast material–enhanced MR examinations days to weeks before developing NSF (9). This association has been reinforced by the results of subsequent studies in which gadolinium was detected in the tissues of patients with NSF and in autopsy specimens from patients who had had NSF (10–13). Animal studies have also revealed NSF in rats that were repeatedly infused with gadodiamide (Omniscan; GE Healthcare, Princeton, NJ) (14).

The prevention of NSF is a priority at our institution. In May 2007, we developed a set of restrictive GBCA guidelines to protect patients, particularly those with existing or risk factors for renal disease, against potentially devastating and irreversible complications of GBCA administration. The purpose of our investigation was to retrospectively determine the incidence of NSF in a large academic medical center (Massachusetts General Hospital) after the adoption of restrictive GBCA administration guidelines. We compared the incidence of NSF during the post–guidelines adoption period (hereafter postadoption period) between January 2008 and March 2010 with the incidence of NSF during the pre–guidelines adoption and transitional period between January 2002 and December 2007.

**Materials and Methods**

**Restrictive GBCA Guidelines**

This retrospective Health Insurance Portability and Accountability Act–compliant study was approved by our hospital’s (Massachusetts General Hospital) institutional review board. The requirement for informed patient consent was waived. Restrictive GBCA guidelines were implemented in May 2007. For patients who are receiving chronic dialysis treatment, alternative imaging such as ultrasonography, nonenhanced MR imaging, and nonenhanced computed tomography (CT) is first considered. For example, contrast-enhanced CT examinations performed with low-osmolar or iso-osmolar agents, as compared with contrast-enhanced MR examinations, can yield equivalent—and in the appropriate setting, superior—diagnostic information. Moreover, prophylactic hemodialysis can reduce the levels of intravenous contrast material in plasma (15,16) and has the potential to lower the risk of contrast agent–related nephropathy. If the radiologist and referring physician decide that a contrast-enhanced MR examination is indicated, they will determine, in consultation with the nephrology service, whether the patient may benefit from postprocedural hemodialysis. The hemodialysis should be performed promptly after injection of the GBCA. We require written informed consent from the patient. The administered dose is weight based (0.2 mL per kilogram of body weight), and the maximal dose is limited to 20 mL.

Patients aged 18–60 years with no risk factors for renal disease (ie, prior history of acute or chronic renal disease, diabetes mellitus, systemic lupus, or multiple myeloma) are not required to have their serum creatinine level measured before the contrast-enhanced MR examination.

Patients who are older than 60 years and those who are younger than 60 years and have risk factors are screened by means of serum creatinine level measurement and estimated glomerular filtration rate (eGFR) calculation within 30 days before the MR study date. If the eGFR is found to be lower than

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**Advance in Knowledge**

- After the implementation of restrictive gadolinium-based contrast agent (GBCA) guidelines, no new cases of nephrogenic systemic fibrosis (NSF) were diagnosed at our institution, indicating a reduction in the incidence of NSF from three cases per 10,000 contrast-enhanced MR examinations performed during the pre–guidelines adoption and transitional period to zero cases per all examinations performed during the post–guidelines adoption period.

**Implications for Patient Care**

- The absence of NSF cases after the adoption of restrictive GBCA guidelines suggests that these guidelines are effective in preventing NSF.
- Gadopentetate dimeglumine can be safely administered under these conditions, even in patients with an estimated glomerular filtration rate lower than 60 mL/min/m².
60 mL/min/m², an alternative imaging procedure is considered. The availability of potentially renoprotective therapies, such as N-acetyl-L-cysteine, hydration, and bicarbonate treatments, may make iodinated contrast-enhanced CT a safer alternative to contrast-enhanced MR imaging for these patients. If the contrast-enhanced MR examination remains the preferred diagnostic option, the decision to administer a GBCA will depend on the severity of renal disease (Table 1).

In response to emerging data from our institution implicating gadopentetate dimeglumine use in the development of NSF (17), in October 2007 we replaced gadopentetate dimeglumine (Magnevist; Bayer Healthcare Pharmaceuticals, Wayne, NJ) with gadobenate dimeglumine (Multihance; Bracco Diagnostics, Milan, Italy) as the sole GBCA used for patients with an eGFR lower than 60 mL/min/m². We continued to use gadopentetate dimeglumine for patients who had preserved renal function and no risk factors for renal disease. We discontinued the use of gadobenate dimeglumine in December 2008 after observing a higher rate of acute adverse allergic reactions with gadobenate dimeglumine (0.28%) as compared with gadopentetate dimeglumine (0.14%). We also observed two cases of severe reaction after administering gadobenate dimeglumine. These data were previously published by Abujudeh et al (18).

Identification of Contrast-enhanced MR Examinations
We identified all cases of contrast-enhanced MR examinations performed during the pre–guidelines adoption period (hereafter preadoption period) between January 2002 and April 2007, the transitional period between May and December 2007, and the postadoption period between January 2008 and March 2010 by querying a database mirror of our department’s radiology information system (19). This search was performed by using the radiology information system fields for the examination code maintained for billing purposes. For each such examination, data regarding the patient’s renal function were extracted by using a programmatic interface to the electronic medical record (20). The value and date of the lowest eGFR measurement were identified before each contrast-enhanced MR examination. For each creatinine value, an eGFR was calculated by using the Modification of Diet in Renal Disease study method (21); however, no correction was made for African-American race.

We reviewed the electronic medical record for each patient who underwent a contrast-enhanced MR examination during the postadoption period despite having an eGFR lower than 30 mL/min/m². The indication for each contrast-enhanced MR examination was recorded. We queried for the terms NSF and fibrosis (20); references to fibrosis within the context of conditions such as pulmonary fibrosis, healing skeletal fractures, and ocular fibrosis were excluded. We also queried for the term dialysis, recording whether the patient was receiving dialysis treatment at the time of the contrast-enhanced MR examination.

Identification of NSF Cases
As described by Abujudeh et al (17,22), our institution’s pathology database was previously searched for cases of NSF confirmed with biopsy between January 2002 and December 2007.

We searched our institution’s pathology database for any new histopathologically confirmed cases of NSF diagnosed between January 2008 and September 2010, allowing at least 6 months of follow-up for all patients included for this study period. We used the search terms nephrogenic and fibrosis.

Statistical Analysis
Paired Z tests were used to compare the percentage of contrast-enhanced MR examinations performed during the preadoption and translational period—between January 2002 and December 2007—with the percentage of MR examinations performed during the postadoption period—between January 2008 and March 2010—as stratified according to eGFR levels (Microsoft Excel, version 2003; Redmond, Wash). The paired Z test was also used to compare the incidence of histopathologically confirmed NSF cases following contrast-enhanced MR imaging during the preadoption and translational period with the incidence of such cases during the postadoption period. P < .05 indicated statistical significance.

Results
Contrast-enhanced MR Examinations
During the preadoption and transitional period, a total of 113 120 contrast-enhanced MR examinations were performed in adult patients. Of these 113 120 examinations, 75 815 (67%) were performed in patients in whom a creatinine level measurement was obtained within 30 days before the MR study date. Fifty-five percent (n = 62 682) of the 113 120 MR examinations were performed in patients with an eGFR of 60 mL/min/m² or higher, 11% (n = 11 846) of the examinations were performed in patients with an eGFR of 30–59 mL/min/m², and 1.1% (n = 1287) of the examinations were performed in patients with an eGFR lower than 30 mL/min/m². These data are summarized in Table 2.

During the postadoption period, 52 954 contrast-enhanced MR examinations were performed in adult patients. Of these 52 954 MR examinations, 39 087 (74%) were performed in patients in whom a creatinine level measurement was obtained within 30 days before the MR study date. Sixty-two percent (n = 32 597) of the 52 954 MR examinations were performed in patients with an eGFR of 60 mL/min/m² or higher. Twelve percent (n = 6490) of the MR examinations were performed in patients with an eGFR lower than 60 mL/min/m², and 99.4% (n = 6454) of these 6490 examinations were performed in patients with eGFRs of 30–59 mL/min/m². Thirty-six (0.07%) of the 52 954 contrast-enhanced MR examinations were performed in patients with an eGFR lower than 30 mL/min/m².

Regarding the contrast-enhanced MR examinations performed in the patients with an eGFR lower than 30 mL/min/m², the most common indication was the search for recurrent or progressive disease in the setting of a preexisting malignancy—for example, metastasis to
the spinal cord—as the cause for acute symptoms. The other indications were the search for infection, such as epidural abscess, as the cause for acute symptoms; the search for primary malignancy, such as hemorraghic brain tumor, as the cause for acute symptoms; and further characterization of findings detected at an alternative imaging study or physical examination, such as a large soft-tissue mass suspected to be sarcoma (Table 3). Four of these patients were receiving hemodialysis treatment at the time of the contrast-enhanced MR examination, and one patient required dialysis later, after the MR examination. There was no mention of dialysis in the electronic medical records for the remaining 31 patients. There was no mention of NSF or fibrosis in the medical records for any patient with an eGFR lower than 30 mL/min/m².

### Review of American College of Radiology Contrast Agent Guidelines

The American College of Radiology (ACR) classifications of GBCAs (23), based on reported numbers of NSF cases associated with the administration of each agent, are summarized in Table 4. The ACR’s recommendations for administering GBCAs when imaging high-risk patients are summarized in the Figure. ACR recommendations for using GBCAs in contrast-enhanced MR examinations performed in patients who have an eGFR lower than 60 mL/min/m² and/or are receiving chronic dialysis treatment are summarized in Table 5.

### NSF Cases

Review of previously published data from our institution revealed 34 cases of clinicopathologically confirmed cases of NSF associated with GBCA administration during the preadoption and transitional period between January 2002 and December 2007. Review of the pathology records revealed no new cases of clinicopathologically confirmed NSF cases during the postadoption period between January 2008 and March 2010.

### Statistical Analysis

The percentage of contrast-enhanced MR examinations performed in patients with a recently obtained (within 30 days before the examination) eGFR measurement was lower during the preadoption and transitional period (67% [75 815 of 113 120]) than during the postadoption period (74% [39 087 of 52 954]); the difference was significant (P < .01). The proportion of contrast-enhanced MR examinations performed in patients with eGFRs of 30–59 mL/min/m² was lower during the preadoption and transitional period (11 846 of 113 120 [11%]) than during the postadoption period (6454 of 52 954 [12%]); this difference also was significant (P < .01). The percentage of contrast-enhanced MR examinations performed in patients with eGFRs lower than 30 mL/min/m² was significantly lower during the postadoption period (0.07% [36 of 52954]) than during the preadoption and transitional period (1.1% [1287 of 113120]) (P < .01).

The incidence of NSF during the preadoption and transitional period was

### Table 1

<table>
<thead>
<tr>
<th>Renal Disease Severity</th>
<th>Guideline</th>
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<tbody>
<tr>
<td>eGFR &gt; 60 mL/min/m²</td>
<td>GBCA can be administered as indicated.</td>
</tr>
<tr>
<td>eGFR 30–59 mL/min/m²</td>
<td>Weight-based dose of GBCA (0.2 mL/kg) can be administered, with maximal dose of 20 mL allowed within 24 hours.</td>
</tr>
<tr>
<td>eGFR &lt; 30 mL/min/m²</td>
<td>GBCA cannot be administered, except in cases of medical necessity.</td>
</tr>
</tbody>
</table>

Note.—GBCA administration guidelines developed and used at the authors’ institution are listed.

### Table 2

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Postadoption Period</th>
<th>Preadoption and Transitional Period</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total no. of contrast-enhanced MR examinations performed</td>
<td>29 087 (74)</td>
<td>75 815 (67)</td>
</tr>
<tr>
<td>No. of documented examinations with available eGFR measurements</td>
<td>32 978 (62)</td>
<td>62 682 (55)</td>
</tr>
<tr>
<td>eGFR ≥ 60 mL/min/m²</td>
<td>6454 (12)</td>
<td>11 846 (11)</td>
</tr>
<tr>
<td>eGFR &lt; 30 mL/min/m²</td>
<td>36 (0.07)</td>
<td>1287 (1.1)</td>
</tr>
</tbody>
</table>

Note.—Data are numbers of contrast-enhanced MR examinations performed at the authors’ institution during the postadoption period (between January 2008 and March 2010) and the preadoption and transitional period (between January 2002 and December 2007), subdivided by severity of renal disease. Numbers in parentheses are percentages.

### Table 3

<table>
<thead>
<tr>
<th>Indication</th>
<th>No. of Examinations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Search for infection or recurrence of known malignancy as cause of acute symptoms</td>
<td>13</td>
</tr>
<tr>
<td>Search for primary malignancy as cause of acute symptoms</td>
<td>7</td>
</tr>
<tr>
<td>Further characterization of finding noted at physical examination or alternative imaging</td>
<td>9</td>
</tr>
</tbody>
</table>

### Table 4

<table>
<thead>
<tr>
<th>Indication</th>
<th>No. of Examinations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Search for progression or recurrence of known malignancy as cause of acute symptoms</td>
<td>13</td>
</tr>
<tr>
<td>Search for infection as cause of acute symptoms</td>
<td>7</td>
</tr>
<tr>
<td>Search for primary malignancy as cause of acute symptoms</td>
<td>9</td>
</tr>
<tr>
<td>Further characterization of finding noted at physical examination or alternative imaging</td>
<td>7</td>
</tr>
</tbody>
</table>
approximately three cases per 10000 contrast-enhanced MR examinations. No new cases of NSF were documented during the postadoption period. The reduced incidence of NSF was significant \( P < .01 \).

**Discussion**

This investigation was a large single-institution study designed to examine the incidence of NSF after the adoption of restrictive GBCA administration guidelines. Our postadoption period was characterized by a higher percentage of contrast-enhanced MR examinations involving preexamination creatinine level determinations (74% [39087 of 52954] vs 67% [75815 of 113120] of examinations performed during preadoption and transitional period) and a lower percentage of these examinations performed in patients with eGFRs lower than 30 mL/min/m\(^2\) (0.07% [36 of 52954] vs 1.1% [1287 of 113120] of examinations performed during preadoption and transitional period). These data suggest our referring physicians’ and radiologists’ overall compliance to the guidelines and increased awareness of the risks associated with GBCA use, especially in the setting of renal impairment.

The percentage of NSF cases diagnosed at our institution during the preadoption and transitional period was consistent with the rates published in the literature. For example, Prince et al (24) reported 15 cases (0.02%) of NSF diagnosed after 83131 contrast-enhanced MR examinations performed at two large medical centers between January 1997 and June 2007 (a span similar to that of our preadoption period). This rate was not significantly different from the 0.03% rate of NSF in the current study: 34 cases of NSF diagnosed among 113000 contrast-enhanced MR examinations (approximately three cases per 10000 contrast-enhanced MR examinations).

No new cases of NSF were detected during the postadoption period, even among those patients with eGFRs lower than 60 mL/min/m\(^2\). We believe that our guidelines were successful in preventing NSF because they encompass a number of key observations regarding the use of GBCA published in the literature. Data from Abujudeh et al (22) indicate that patients who receive higher cumulative doses of gadopentetate dimeglumine have a higher risk of developing NSF compared with those who receive lower doses. To prevent excessive GBCA administration at our institution, we offered alternative imaging examinations and limited the maximal weight-based dose of GBCA administered for each contrast-enhanced MR examination to 20 mL for any patient with renal disease. These measures may have been protective for patients with eGFRs lower than 60 mL/min/m\(^2\).

The patients who were receiving chronic dialysis treatment and the patients with eGFRs lower than 30 mL/min/m\(^2\) received a nephrology consultation and underwent hemodialysis within 24 hours after the contrast-enhanced MR examination, if hemodialysis was deemed to be appropriate. Timely post-procedural hemodialysis can reduce the transit time of GBCA in the circulation. Okada et al (25) estimated that 78% of circulating gadolinium chelates are eliminated during a single session of hemodialysis and that 95% of circulating gadolinium chelates are eliminated after a second session of hemodialysis.

### Table 4

**ACR Classifications of GBCAs**

<table>
<thead>
<tr>
<th>GBCA</th>
<th>Trade Name and Manufacturer*</th>
</tr>
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<tbody>
<tr>
<td>Group I: agents associated with greatest number of NSF cases</td>
<td></td>
</tr>
<tr>
<td>Gadodiamide</td>
<td>Omniscan (GE Healthcare)</td>
</tr>
<tr>
<td>Gadopentetate dimeglumine</td>
<td>Magnevist (Bayer Healthcare Pharmaceuticals)</td>
</tr>
<tr>
<td>Gadoversetamide</td>
<td>OptiMARK (Coviden)</td>
</tr>
<tr>
<td>Group II: agents associated with few, if any, unconfounded cases of NSF</td>
<td></td>
</tr>
<tr>
<td>Gadobenate dimeglumine</td>
<td>MultiHance (Bracco Diagnostics)</td>
</tr>
<tr>
<td>Gadoteridol</td>
<td>ProHance (Bracco Diagnostics)</td>
</tr>
<tr>
<td>Gadoteric acid‡</td>
<td>Dotarem (Guerbet)</td>
</tr>
<tr>
<td>Gadobutrol†</td>
<td>Gadovist (Bayer Healthcare Pharmaceuticals)</td>
</tr>
<tr>
<td>Group III: agents that have only recently appeared on the market in the United States‡</td>
<td></td>
</tr>
<tr>
<td>Gadofosveset</td>
<td>Ablavar (Lanthemus Medical Imaging)</td>
</tr>
<tr>
<td>Gadoteric acid</td>
<td>Evovist (Bayer Healthcare Pharmaceuticals)</td>
</tr>
</tbody>
</table>

Note.—The cited ACR classifications of GBCAs are based on reported numbers of NSF cases associated with the administration of each agent (21).

* Manufacturer locations: Covidien, Hazelwood, Mo; Guerbet, Aulnay-sous-Bois, France; Lantheus Medical Imaging, Billerica, Mass.

† Not approved by the Food and Drug Administration for use in the United States.

‡ There are limited data regarding these agents; however, few, if any, unconfounded cases of NSF associated with the administration of these agents have been reported.

1. Consider alternative examinations that do not require administration of GBCA.
2. Use lowest amount of GBCA necessary to obtain clinical information.
3. Avoid double- and triple-dose studies.
4. Avoid Group 1 GBCAs, which are associated with the highest rates of NSF.
5. Inform referring physicians and patients of the risks of GBCA use and proceed with contrast-enhanced MR examinations only if both referring physicians and patients agree to stated risks.

ACR recommendations for administering GBCAs when imaging high-risk patients. Group 1 GBCAs are described and listed in Table 4.
The recent Food and Drug Administration guidelines, published in September 2010, stipulate that gadodiamide, gadopentetate dimeglumine, and gadoversetamide will be labeled as “inappropriate for use among patients with acute kidney injury or chronic severe kidney disease” (26). The 2010 ACR guidelines further classify known GBCAs into groups based on the reported numbers of NSF cases associated with each agent (23). It should be noted that the ACR advises the use of group II or III GBCAs, one of which is gadodextrin, rather than group I GBCAs for patients who are receiving chronic dialysis treatment and/or have eGFRs lower than 60 mL/min/m². We identified no new cases of NSF in any patient who underwent contrast-enhanced MR imaging with gadobenate dimeglumine or gadopentetate dimeglumine. Previously published data from our institution, however, did indicate that the rate of acute adverse allergic reactions was higher with gadobenate dimeglumine (0.28%) than with gadopentetate dimeglumine (0.14%). We could not conclude that the difference in rate of allergic reactions between these two agents was significant because the characteristics of the patient populations who underwent these examinations were different. However, two cases of severe reaction—a case of seizure and a case of cardiopulmonary arrest—followed the administration of gadobenate dimeglumine (18). For these reasons, we discontinued the use of this agent in December 2008 and resumed our use of gadopentetate dimeglumine in all patients going contrast-enhanced MR examinations. While this practice is a deviation from the latest ACR recommendations, the absence of new observed cases of NSF during the postadoption period suggests that gadopentetate dimeglumine can be used safely, as long as the administration is in accordance with our GBCA guidelines.

The 2010 ACR recommendations include a second Food and Drug Administration–approved GBCA, gadoteridol, for consideration in patients who are receiving chronic dialysis treatment and/or have eGFRs lower than 60 mL/min/m² if contrast-enhanced MR imaging is deemed necessary (23). Our institution has no experience with gadoteridol, and data regarding its association with NSF are limited.

Our study had a number of limitations. It was retrospective in nature. The histopathologic follow-up period ranged from 6 to 33 months (January 2008 through September 2010), after the adoption of the restrictive GBCA guidelines in May 2007. We chose to include data from the transitional period (May to December 2007) in the preadoption period data analysis rather than the postadoption period data analysis because compliance was probably uneven during the transitional period. Most cases of NSF reported in the literature developed within 2–3 months after exposure to the GBCA, minimizing the importance of extended follow-up; however, a latency period of up to 18 months has been reported (13). We also realize that because we searched our institution’s pathology database for only new cases of NSF, some patients who underwent a contrast-enhanced MR examination at our institution may have subsequently transferred their care to another institution, where the histopathologic diagnosis of NSF could have been made. We are not aware of any such cases, and this scenario is unlikely because our institution is part of an extensive network of hospitals with a shared medical record system.

In summary, we believe that the adoption of restrictive GBCA guidelines probably prevented the occurrence of new cases of NSF at our institution and that it facilitates the safe use of gadopentetate dimeglumine, even in patients who are undergoing chronic dialysis treatment and/or have eGFRs lower than 60 mL/min/m². In the future, we will continue to refine our GBCA guidelines by customizing

### Table 5

**ACR Recommendations for GBCA Use in Contrast-enhanced MR Imaging in Patients with eGFRs Lower than 60 mL/min/m² and/or Receiving Chronic Dialysis Treatment**

<table>
<thead>
<tr>
<th>Patient Group</th>
<th>Recommendations*</th>
</tr>
</thead>
<tbody>
<tr>
<td>eGFR &lt; 30 mL/min/m², receiving chronic dialysis treatment</td>
<td>Consider performing iodinated contrast-enhanced CT. Avoid administering group I GBCA if contrast-enhanced MR examination must be performed. Use lowest possible dose of GBCA needed to obtain diagnostic images. Perform contrast-enhanced MR examination as closely before hemodialysis as possible. Consider performing multiple dialysis sessions after GBCA administration.</td>
</tr>
<tr>
<td>eGFR &lt; 30 mL/min/m², not receiving chronic dialysis treatment</td>
<td>Use lowest possible GBCA dose needed to obtain diagnostic images if contrast-enhanced MR examination must be performed. Avoid use of group I GBCAs. Avoid readministering GBCA for several days to a week.</td>
</tr>
<tr>
<td>eGFR ≥ 30 mL/min/m² but &lt; 60 mL/min/m²</td>
<td>Use lowest possible dose of GBCA needed to obtain diagnostic images.</td>
</tr>
<tr>
<td>eGFR 45–59 mL/min/m²</td>
<td>Use recommendations for patients with eGFR &lt; 30 mL/min/m² not receiving chronic dialysis treatment.</td>
</tr>
<tr>
<td>eGFR 30–44 mL/min/m²</td>
<td>Use lowest possible dose of GBCA needed to obtain diagnostic images.</td>
</tr>
</tbody>
</table>

* Group I GBCAs are described and listed in Table 4.
the quantity and type of GBCA for each contrast-enhanced MR examination according to the indication and the anatomy being imaged so that only the smallest amount of GBCA sufficient to provide diagnostic-quality images is administered.

Disclosures of Potential Conflicts of Interest: Y.W. No potential conflicts of interest to disclose. T.K. A. No potential conflicts of interest to disclose. O.N. No potential conflicts of interest to disclose. R.M.N. No potential conflicts of interest to disclose. R.K. No potential conflicts of interest to disclose. J.K. Financial activities related to the present article: none to disclose. Financial activities not related to the present article: none to disclose. H.I.A. Financial activities related to the present article: none to disclose. Financial activities not related to the present article: received a research grant from Bracco Diagnostics. Other relationships: none to disclose.

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