Incidence and risk of developing contrast-induced acute kidney injury following intravascular contrast administration in elderly patients

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Background: The purpose of this meta-analysis was to evaluate the epidemiology of contrast-induced acute kidney injury (CI-AKI) in the elderly.

Methods: A literature review was undertaken to determine the incidence of CI-AKI in individuals receiving intravascular contrast medium in the hospital setting.

Results: Twenty-two studies with 186,455 patients were identified. The pooled incidence of CI-AKI was 13.6% in 67,831 patients older than 65 years of age (95% confidence interval [CI] 10.1–18.2, \( I^2 = 0.496 \)). The pooled odds ratio of CI-AKI in the elderly was 2.55 (95% CI 1.85–3.52, \( I^2 = 0.34 \)). The high incidence of CI-AKI in the elderly was consistent across different administration route subgroups (intracoronary contrast medium group, 15.5% [95% CI 10.3–22.6]; intravenous contrast medium group, 12.4% [95% CI 8.0–18.8]).

Conclusion: Elderly patients are at greater risk for developing CI-AKI.

Keywords: contrast-induced acute kidney injury, angiography, enhanced computed tomography, epidemiology, meta-analysis

Introduction
Contrast-induced acute kidney injury (CI-AKI) following administration of intravascular contrast media (CM) is currently the third leading cause of hospital-acquired acute kidney injury and occurs in approximately 7% of unselected patients.\(^1,2\) Advanced age has been identified as an important risk factor for CI-AKI.\(^3\) However, limited data exist to determine the actual epidemiology of CI-AKI in elderly patients. To address this issue, we performed a meta-analysis on currently available clinical studies to evaluate the incidence and risk of CI-AKI developing in the elderly.

Materials and methods
Search strategy
We derived three comprehensive search themes that were combined by the Boolean operator “AND” (see Supplementary material). For the theme “CI-AKI”, the following combinations of medical subject heading terms and text words were used: “contrast induced acute kidney injury”, “contrast induced acute renal failure”, “contrast nephropathy”, “contrast induced nephropathy”, “contrast induced nephrotoxicity”, “contrast associated nephropathy”, “contrast associated nephrotoxicity”, and “radiocontrast induced nephropathy”. For the theme “elderly”, the terms “elderly”, “aged”, “geriatric”, “older”, “senior”, “age group”, “old persons”, “65 years”, “75 years”, and...
“80 years” were used. For the theme “clinical study”, we used a previously published search strategy.4

**Study selection and data extraction**

We included cohort studies and randomized controlled trials that reported the incidence or adjusted odds ratios (ORs) of CI-AKI following intravascular CM administration in elderly patients. An elderly patient was defined as a patient ≥65 years of age. There were no restrictions regarding patient inclusion criteria or administration route of CM. The exclusion criterion was a duplicate report. The studies were reviewed by two independent investigators (WS and TZ) to determine whether the studies met the inclusion criteria. Discrepancies were resolved by consensus between the two review authors when the discrepancy was due to simple oversight by one of these authors. Otherwise, a third author was consulted when the discrepancy was due to a difference in interpretation. Data from included studies were recorded using a standardized form, including the source and design of the studies, inclusion/exclusion criteria, baseline characteristics of participants, and outcomes.

**Endpoints, data synthesis, and analysis**

The endpoint was the incidence of CI-AKI, which was defined as an increase in serum creatinine levels of more than 25% or 0.5 mg/dL following intravascular CM administration.2 If data for this definition were unavailable, the endpoint of CI-AKI reported in the original study was chosen. The overall incidence of CI-AKI in the elderly was estimated with 95% confidence intervals (CIs) by pooling the reported incidences of CI-AKI from individual studies according to the DerSimonian-Laird random-effect model using MetaAnalyst software (version Beta3.13; Tufts Medical Center, Boston, MA, USA).5 The incidence of CI-AKI in prespecified subgroups was also analyzed, including patients aged ≥75 years and ≥80 years of age, with intracoronary CM administration, intra-arterial CM administration other than via the coronary artery, intravenous CM administration, and administration route other than via coronary artery. Pooled ORs of CI-AKI in elderly patients versus younger patients were estimated according to the inverse-variance random-effect model using Review Manager software (Rev-Man Analyses version 5.1.4; Copenhagen, Denmark; The Nordic Cochrane Center, The Cochrane Collaboration, 2011) by pooling the calculated ORs based on the incidence of CI-AKI in the two groups and the reported adjusted ORs from individual studies. Heterogeneity between studies was analyzed by the F statistic. An F less than 50% indicated that the magnitude of heterogeneity may not be important. To explore sources of heterogeneity, metaregression in incidence of CI-AKI was performed using the restricted maximum likelihood method by Stata version 12.0 (Stata Corporation, College Station, TX, USA). Definition of elderly (≥65 years or ≥75 years), definition of CI-AKI (serum creatinine increase ≥25% or 0.5 mg/dL, or others), and route of CM administration (intravenous or intra-arterial) were used as covariates in the regression model. Sensitivity analysis was performed by sequentially excluding a single study. P-values less than 0.05 in two-tailed tests were considered to be statistically significant.

**Results**

We retrieved 159 unique articles. Among these, 32 were excluded based on the abstract alone. The remaining 127 articles included a full-text review, and 105 were excluded for the reasons listed in Figure 1. Consequently, 22 studies (21 cohort studies and one randomized controlled trial) with 186,455 patients were identified using our search criteria.

The routes of CM administration were coronary arteries for coronary angiography or intervention in 14 studies;6–18 periphery arteries other than the coronary artery in two studies;19,20 veins for enhanced computed tomography in five studies;21–25 and both periphery arteries and veins in one study.26 The main characteristics of the study design and participants in the included studies are listed in Table 1.

Among the included 67,831 participants ≥65 years of age, the overall incidence of CI-AKI was 13.6%
Table 1 General characteristics of the included studies

<table>
<thead>
<tr>
<th>Year</th>
<th>Reference</th>
<th>Study location</th>
<th>Recruitment period</th>
<th>Design</th>
<th>Patients (n)</th>
<th>Definition of elderly (years)</th>
<th>Definition of CI-AKI</th>
<th>Patient characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>2007</td>
<td>Cheruvu et al</td>
<td>NY, USA</td>
<td>November 2003 to June 2005</td>
<td>Retrospective</td>
<td>568</td>
<td>≥70</td>
<td>SCr ≥0.5 mg/dL or 25%</td>
<td>Patients undergoing contrast-enhanced CT and receiving iodixanol</td>
</tr>
<tr>
<td>2008</td>
<td>Hipp et al</td>
<td>NY, USA</td>
<td>January 2004 to August 2005</td>
<td>Retrospective</td>
<td>235</td>
<td>≥75</td>
<td>SCr ≥0.5 mg/dL or 25%</td>
<td>Trauma patients undergoing contrast-enhanced CT</td>
</tr>
<tr>
<td>2011</td>
<td>Matsushima et al</td>
<td>PA and TX, USA</td>
<td>January 2007 to December 2007</td>
<td>Retrospective</td>
<td>1,184</td>
<td>≥65</td>
<td>SCr ≥0.5 mg/dL or 25%</td>
<td>Trauma patients undergoing contrast-enhanced CT</td>
</tr>
<tr>
<td>2012</td>
<td>Finigan et al</td>
<td>CA, USA</td>
<td>2010</td>
<td>Retrospective</td>
<td>118</td>
<td>≥65</td>
<td>SCr ≥0.5 mg/dL or 25%</td>
<td>Elderly trauma patients undergoing contrast-enhanced CT</td>
</tr>
<tr>
<td>2012</td>
<td>Huang et al</td>
<td>Taiwan</td>
<td>January 2007 to June 2007</td>
<td>Retrospective</td>
<td>594</td>
<td>≥65</td>
<td>SCr ≥0.5 mg/dL</td>
<td>Elderly patients undergoing contrast-enhanced CT in emergency department</td>
</tr>
<tr>
<td>2011</td>
<td>Plaisance et al</td>
<td>MI, USA</td>
<td>January 2001 to December 2008</td>
<td>Prospective</td>
<td>7,764</td>
<td>≥70</td>
<td>SCr ≥0.5 mg/dL</td>
<td>Patients undergoing percutaneous lower extremity peripheral vascular intervention</td>
</tr>
<tr>
<td>2012</td>
<td>Zhao et al</td>
<td>Beijing, People’s Republic of China</td>
<td>January 2003 to January 2010</td>
<td>Retrospective</td>
<td>81</td>
<td>≥65</td>
<td>SCr ≥0.5 mg/dL or 25%</td>
<td>Elderly patients undergoing percutaneous transluminal renal angioplasty with stent implantation</td>
</tr>
<tr>
<td>2013</td>
<td>Ray et al</td>
<td>TX, USA</td>
<td>July 2010 to June 2011</td>
<td>Retrospective</td>
<td>75</td>
<td>≥75</td>
<td>SCr ≥0.3 mg/dL or 50% or oligurine</td>
<td>Patients with subarachnoid hemorrhage undergoing cerebral angiography or contrast-enhanced CT</td>
</tr>
<tr>
<td>1990</td>
<td>Rich and Crecelius</td>
<td>WA, USA</td>
<td>July 1987 to May 1988</td>
<td>Prospective</td>
<td>183</td>
<td>≥70</td>
<td>SCr ≥0.5 mg/dL</td>
<td>Elderly patients undergoing coronary angiography</td>
</tr>
<tr>
<td>2004</td>
<td>Mehran et al</td>
<td>NY, USA</td>
<td>NA</td>
<td>Prospective</td>
<td>4,898</td>
<td>≥75</td>
<td>SCr ≥0.5 mg/dL or 25%</td>
<td>Patients undergoing PCI</td>
</tr>
<tr>
<td>2004</td>
<td>Marenzi et al</td>
<td>Milan, Italy</td>
<td>January 2001 to June 2003</td>
<td>Prospective</td>
<td>208</td>
<td>≥75</td>
<td>SCr ≥0.5 mg/dL</td>
<td>AMI patients undergoing primary PCI</td>
</tr>
<tr>
<td>2006</td>
<td>Toprak et al</td>
<td>Turkey</td>
<td>September 2002 to January 2005</td>
<td>Prospective</td>
<td>219</td>
<td>≥70</td>
<td>SCr ≥25%</td>
<td>Patients with reduced kidney function undergoing nonemergent coronary angiography</td>
</tr>
<tr>
<td>2007</td>
<td>Miranda Malpica et al</td>
<td>Mexico</td>
<td>January 1997 to November 2004</td>
<td>Retrospective</td>
<td>73</td>
<td>≥80</td>
<td>SCr ≥0.5 mg/dL or 25%</td>
<td>Elderly patients undergoing PCI</td>
</tr>
<tr>
<td>2007</td>
<td>Sosnowski et al</td>
<td>Poland</td>
<td>NA</td>
<td>Retrospective</td>
<td>63</td>
<td>≥80</td>
<td>NA</td>
<td>Elderly AMI patients undergoing PCI</td>
</tr>
<tr>
<td>2008</td>
<td>Morikawa et al</td>
<td>Japan</td>
<td>NA</td>
<td>RCT</td>
<td>254</td>
<td>≥70</td>
<td>SCr ≥0.5 mg/dL or 25%</td>
<td>Patients with SCr ≥1.3 mg/dL undergoing coronary angiography received either ANP or Ringer solution alone</td>
</tr>
<tr>
<td>2008</td>
<td>Sidhu et al</td>
<td>NY, USA</td>
<td>January 1998 to July 2006</td>
<td>Prospective</td>
<td>13,127</td>
<td>≥65</td>
<td>SCr ≥0.5 mg/dL or 25%</td>
<td>Patients undergoing coronary angiography</td>
</tr>
</tbody>
</table>

(Continued)
Table 1 (Continued)

<table>
<thead>
<tr>
<th>Year</th>
<th>Design</th>
<th>Recruitment period</th>
<th>Study location</th>
<th>Reference</th>
<th>Patients undergoing PCI</th>
<th>Patients with sCr $\geq 1.5$ mg/dl undergoing PCI</th>
<th>Patients with sCr $\geq 2$ mg/dl undergoing PCI</th>
<th>Patients with sCr $\geq 1.5$ mg/dl undergoing PCI</th>
</tr>
</thead>
<tbody>
<tr>
<td>2011</td>
<td>Prospective</td>
<td>February 2010 to January 2011</td>
<td>Prato, Italy</td>
<td>Thomas et al.</td>
<td>133,34</td>
<td>93,34</td>
<td>57,34</td>
<td>45,34</td>
</tr>
<tr>
<td>2012</td>
<td>Prospective</td>
<td>March 2011 to February 2012</td>
<td>Tianjin, People's Republic of China</td>
<td>Fei et al.</td>
<td>136,35</td>
<td>105,35</td>
<td>70,35</td>
<td>60,35</td>
</tr>
<tr>
<td>2012</td>
<td>Prospective</td>
<td>July 2011 to June 2012</td>
<td>Guangdong People’s Republic of China</td>
<td>Liu et al.</td>
<td>137,36</td>
<td>112,36</td>
<td>75,36</td>
<td>65,36</td>
</tr>
</tbody>
</table>

Abbreviations: AMI, acute myocardial infarction; CI-AKI, contrast-induced acute kidney injury; CT, computed tomography; PCI, percutaneous coronary intervention; rCT, randomized controlled trial.


discussion

In the present study, we report the results of a meta-analysis that pooled the incidence and ORs of CI-AKI in the elderly, categorized into different subsets. To the best of our knowledge, this is the first meta-analysis on this issue.

CI-AKI is an important potential complication following CM-based procedures, including noninvasive enhanced computed tomography or invasive angiography. CI-AKI generally resolves spontaneously in most instances, but patients with CI-AKI tend to experience prolonged hospital stays, increased risk of in-hospital death, and long-term adverse cardiac and renal events. As the population ages, the number of elderly patients referred for CM-based procedures is increasing steadily. On the other hand, limited data regarding the true

(95% CI 10.1–18.2, $F=0.496$, Figure 2). The incidence of CI-AKI in six prespecified subgroups is listed in Table 2. In 12 studies for which the incidence of CI-AKI in both the elderly and younger groups was reported, the pooled OR of CI-AKI in the elderly was 2.10 (95% CI 1.77–2.48, $F=0.77$, Figure 3A). The risk of CI-AKI in the elderly was consistent across the subsets of the different CM administration routes. In six studies for which adjusted ORs of CI-AKI in the elderly were reported, the pooled OR of CI-AKI in the elderly was 2.55 (95% CI 1.85–3.52, $F=0.34$, Figure 3B).

The metaregression showed that the regression model explained 65.33% of total between-study variance in incidence of CI-AKI. Definition of elderly was associated with and explained a statistically significant degree of variability ($P=0.002$). The metaregression model is presented in Table 3. The sensitivity analysis suggested that no single study strongly influenced the overall results, because sequentially excluding one individual study at a time did not affect the movement of the point estimate outside the 95% CI (data not shown).

Discussion

In the present study, we report the results of a meta-analysis that pooled the incidence and ORs of CI-AKI in the elderly, categorized into different subsets. To the best of our knowledge, this is the first meta-analysis on this issue.

CI-AKI is an important potential complication following CM-based procedures, including noninvasive enhanced computed tomography or invasive angiography. CI-AKI generally resolves spontaneously in most instances, but patients with CI-AKI tend to experience prolonged hospital stays, increased risk of in-hospital death, and long-term adverse cardiac and renal events. As the population ages, the number of elderly patients referred for CM-based procedures is increasing steadily. On the other hand, limited data regarding the true
Table 2 Incidence of CI-AKI in prespecified subgroups

<table>
<thead>
<tr>
<th>Subgroup</th>
<th>Studies (n)</th>
<th>Patients (n)</th>
<th>Estimated incidence (%)</th>
<th>95% CI</th>
<th>P statistic</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Age (years)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>≥75</td>
<td>12</td>
<td>23,007</td>
<td>16.5</td>
<td>11.7–22.7</td>
<td>0.494</td>
</tr>
<tr>
<td>≥80</td>
<td>6</td>
<td>20,778</td>
<td>13.5</td>
<td>8.6–20.6</td>
<td>0.495</td>
</tr>
<tr>
<td><strong>CM administration routes</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IC</td>
<td>11</td>
<td>62,935</td>
<td>15.5</td>
<td>10.3–22.6</td>
<td>0.498</td>
</tr>
<tr>
<td>IA, other than via coronary artery</td>
<td>2</td>
<td>3,833</td>
<td>6.5</td>
<td>3.5–12.0</td>
<td>0.416</td>
</tr>
<tr>
<td>IV</td>
<td>5</td>
<td>1,053</td>
<td>12.4</td>
<td>8.0–18.8</td>
<td>0.442</td>
</tr>
<tr>
<td>Other than via coronary artery</td>
<td>8</td>
<td>4,896</td>
<td>11</td>
<td>7.1–16.5</td>
<td>0.471</td>
</tr>
</tbody>
</table>

**Abbreviations:** CI-AKI, contrast-induced acute kidney injury; CI, confidence interval; CM, contrast medium; IA, intra-arterial; IC, intracoronary; IV, intravenous; n, number of participants.
**Table 3** Metaregression model in incidence of CI-AKI

<table>
<thead>
<tr>
<th>Covariates</th>
<th>B* (95% CI)</th>
<th>P-values</th>
<th>Adjusted R²a</th>
</tr>
</thead>
<tbody>
<tr>
<td>Definition of elderly</td>
<td>0.107 (0.047–0.168)</td>
<td>0.002</td>
<td>65.33%</td>
</tr>
<tr>
<td>Definition of CI-AKI</td>
<td>−0.042 (−0.096–0.011)</td>
<td>0.109</td>
<td></td>
</tr>
<tr>
<td>Route of CM administration</td>
<td>−0.006 (−0.070−0.058)</td>
<td>0.844</td>
<td></td>
</tr>
</tbody>
</table>

**Notes:** aCoefficient of covariation; bReflects proportion of variability in between-study variance explained by the metaregression model.

Abbreviations: CI-AKI, contrast-induced acute kidney injury; CI, confidence interval; CM, contrast medium.

incidence and risk of developing CI-AKI in the elderly affect decision-making. Based on our meta-analysis, we found that: the risk of developing CI-AKI in the elderly is over two times higher than in younger patients, even after adjustment for other risk factors; the estimated overall incidence of CI-AKI following intravascular CM administration is 13.6% in the elderly, which is higher than the previously reported incidence in an unselected population;^2^ and the trend of a high incidence of CI-AKI in the elderly is consistent across different administration route subgroups. Thus, advanced age...

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**Figure 3** Odds ratios of CI-AKI in the elderly. (A) Meta-analysis of administration route stratified by pooling the calculated odds ratios based on the incidence of CI-AKI in the elderly and younger groups. (B) Meta-analysis by pooling the reported adjusted odds ratios from individual studies.

**Abbreviations:** AKI, acute kidney injury; CI-AKI, contrast-induced acute kidney injury; CM, contrast medium; RCT, randomized controlled trial; Chi, Chi-square test; CI, confidence interval; df, degrees of freedom; IA, intra-arterial; IC, intracoronary; IV, intravenous; SD, standard deviation; SE, standard error.
should be given serious consideration when referring elderly patients for any CM-based procedure.

Limitations
First, the prevalence of other known risk factors of CI-AKI, such as chronic kidney disease, diabetes, dehydration, and concurrent nephrotoxic medication is high in the elderly. These comorbidities might also play important roles in the development of CI-AKI in the elderly. A metaregression with these risk factors as covariates would investigate the extent of these comorbidities contributing to the onset of CI-AKI in the elderly. However, due to incomplete information of these factors from the original studies, we could not add these factors into our regression model. On the other hand, we had pooled the ORs adjusted by risk factors in our meta-analysis, which might help us to evaluate the sole role of advanced age in the development of CI-AKI. Second, definitions of elderly and CI-AKI varied among the included studies, which brought heterogeneity into our meta-analysis. Metaregression indicated that different definitions of elderly could partially explain the heterogeneity. The age-stratified subgroup analysis we performed would be helpful to reduce the heterogeneity. Although definition of CI-AKI was not shown to be associated with a significant degree of variability by metaregression, the incidence of CI-AKI could have been underestimated in studies using only the absolute increase in serum creatinine as the definition of CI-AKI. Meanwhile, the recently published KDIGO (Kidney Disease: Improving Global Outcomes) guidelines recommended the definition of CI-AKI should be based on both urinary output and changes in serum creatinine, and the severity of CI-AKI should be graded as the same as the definition of acute kidney injury. This criteria was not used in our meta-analysis because the vast majority of clinical trials on CI-AKI used the definition based on serum creatinine alone and without grading. Third, we used just PubMed as a search engine. Although we identified 186,455 patients from 22 studies for the present study, using other search engines might yield more information on the incidence and risk of developing CI-AKI following intravascular contrast administration in elderly patients. Finally, no data regarding the impact of CI-AKI on a patient’s clinical course and prognosis, and no conclusive management strategy for the elderly are available. Further studies are needed to address these issues.

Conclusion
Elderly patients are at greater risk for the development of CI-AKI. The overall incidence of CI-AKI in patients ≥65 years of age is up to 13.6%.

Acknowledgments
We especially thank Dr Jinjin Zhang for his assistance with performing the metaregression and help with revising the Materials and methods section. This work is supported by the Program for Outstanding Medical Academic Leader from Shanghai Municipal Health Bureau.

Author contributions
WS and BH developed the study protocol; WS and TZ performed the literature search; WS, TZ, and JP analyzed the data; WS, LS, and BH interpreted data and prepared the manuscript; and WS, TZ, JP, LS and BH revised the manuscript.

Disclosure
The authors report no conflicts of interest in this work.

References


Supplementary material
Search strategy in MEDLINE
(from 1966 to June 2013)


Three comprehensive search themes were combined by the Boolean operator “AND.”