Acetylcysteine for the Prevention of Renal Outcomes in Patients With Diabetes Mellitus Undergoing Coronary and Peripheral Vascular Angiography

A Substudy of the Acetylcysteine for Contrast-Induced Nephropathy Trial

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Background—Diabetes mellitus represents an independent risk factor for contrast-induced acute kidney injury. We report the results of a prespecified substudy of patients with diabetes mellitus included in the Acetylcysteine for Contrast-Induced Nephropathy Trial (ACT), the largest randomized study evaluating the effects of acetylcysteine for the prevention of contrast-induced acute kidney injury conducted to date.

Methods and Results—From the 2308 patients included in the ACT, 1395 had diabetes mellitus and were considered for the present analysis. The study drugs (acetylcysteine 1200 mg or matching placebo) were administered orally twice daily for 2 doses before and 2 doses after the procedure. The allocation was concealed (central Web-based randomization). Participants, healthcare staff, data collectors, and outcome assessors were blinded. All analysis followed the intention-to-treat principle. The incidence of contrast-induced acute kidney injury (primary end point) was 13.8% in the acetylcysteine group and 14.7% in the control group (relative risk 0.93; 95% confidence interval, 0.69–1.26; P=0.64). A combined end point of death or need for dialysis at 30 days was also similar in both the groups (2.2% and 2.1%, respectively; hazard ratio, 1.07; 95% confidence interval, 0.52–2.19; P=0.86).

Conclusions—In this subanalysis, acetylcysteine did not reduce the risk of contrast-induced acute kidney injury or other clinically relevant outcomes in patients with diabetes mellitus undergoing coronary and peripheral vascular angiography.


Key Words: acetylcysteine ■ contrast-induced acute kidney injury ■ diabetes mellitus ■ randomized controlled trial
WHAT IS KNOWN

- Diabetes mellitus is an independent risk factor for contrast-induced acute kidney injury.
- The efficacy of acetylcysteine for preventing contrast-induced nephropathy has been evaluated in several small-size trials with inconsistent results.

WHAT THE STUDY ADDS

- Acetylcysteine does not reduce the risk of contrast-induced acute kidney injury or other clinically relevant outcomes in patients with diabetes mellitus undergoing coronary and peripheral vascular angiography.

Randomization

After providing written informed consent, patients were randomized in a 1:1 ratio to receive acetylcysteine or placebo. The allocation list was generated in random permuted blocks of variable size (4, 6, 8, or 10) and was stratified by site. To guarantee concealment of the allocation list, randomization was implemented through a 24-hour Web-based automated randomization system.

Study Interventions

The study drugs were packed in identical envelopes containing either 600 mg of oral powder acetylcysteine (Medley, Brazil) or placebo to be diluted in water. The powder and the solution were identical in appearance, taste, and smell. A dose of 1200 mg (2 envelopes) of acetylcysteine or placebo was administered orally every 12 hours, for 2 doses before and 2 doses after the procedure. All decisions about management of patients were at the discretion of the medical team, except that nontrial acetylcysteine was not allowed.

Hydration with 0.9% saline, 1 mL/kg per hour, from 6 to 12 hours before to 6 to 12 hours after angiography, was strongly recommended. However, changes in the total volume or speed of administration were permitted.

Study Procedures

Data were obtained at baseline, in the day of the angiography, between 48 and 96 hours after angiography, and at 30 days after angiography. Baseline data were collected immediately after randomization and before administration of hydration scheme and the study drugs. Data collected at baseline included demographic and clinical characteristics, and the most recent serum creatinine level measured within the past 3 months under stable clinical conditions. In the day of the angiography, we collected data regarding the administration of the study drug, hydration scheme, and angiographic procedure. Between 48 and 96 hours after angiography, we assessed vital status, need for dialysis, need for another angiography, and data regarding the administration of the study drugs and hydration and collected a blood sample for serum creatinine measurement. However, all investigators were strongly recommended to collect the creatinine sample within a 48- to 72-hour interval. Whenever more than 1 measurement was available during the period of 48 to 96 hours, the measure closer to 72 hours was used. We contacted the patients 30 days after the angiography to assess the need for dialysis and the vital status.

End Points

The primary end point of this substudy was the same as the main study: contrast-induced acute kidney injury, defined as a 25% elevation of serum creatinine above baseline between 48 and 96 hours after angiography. The secondary end points were a composite of death or need for dialysis at 30 days, individual components of the composite outcome, doubling or elevation ≥44.2 μmol/L (0.5 mg/dL) in serum creatinine between 48 and 96 hours, cardiovascular deaths at 30 days, and other adverse events. Elevation ≥13.3 μmol/L (0.3 mg/dL) in serum creatinine before angiography, the Acute Kidney Injury Network criteria for acute kidney injury was a post hoc defined end point.

Trial Management

The Coordinating Center resources included procedure manuals, slide sets, and a study Web site. Trained investigators and study coordinators at each site collected the data using a Web-based system. Data quality control was guaranteed by automated data entry checks, weekly contact with investigators, on-site monitoring, and central statistical monitoring. General feedback was provided at investigators’ meetings and in periodic newsletters.

Statistical Analysis

All analyses were performed on an intention-to-treat basis and no postrandomization exclusions were performed. Differences in

intravascular angiographic procedure to receive acetylcysteine 1200 mg or placebo and found no difference in the risk of contrast-induced acute kidney injury or other clinically relevant outcomes. Because diabetes mellitus is an important risk factor for contrast-induced acute kidney injury, it is important to examine the role of acetylcysteine in this group of patients. Results for the subgroup of patients with diabetes mellitus were reported in the primary article of ACT, though not in detail. Thus, the aim of this prespecified subanalysis of the ACT was to investigate if acetylcysteine can prevent acute kidney injury or other clinically relevant outcomes in patients with diabetes mellitus undergoing intravascular angiographic procedures.

Methods

Trial Design

A detailed description of the study design has been published previously.17 Briefly, the ACT was an academic pragmatic randomized (concealed) controlled trial of acetylcysteine versus placebo for preventing contrast-induced acute kidney injury in patients at-risk undergoing an intravascular angiographic procedure conducted in 46 sites in Brazil. Participants, healthcare staff, data collectors, and outcome assessors were blinded to whether patients receive acetylcysteine or placebo. All analyses followed the intention-to-treat principle. The trial was designed by the Steering Committee. The study was approved by the Research Ethics Board of each participant institution and was registered at Clinicaltrials.gov (NCT00736866).

Study Population

Patients undergoing coronary or peripheral arterial diagnostic intravascular angiography or percutaneous intervention were eligible for this subanalysis if they had diabetes mellitus (symptoms of diabetes mellitus plus plasma glucose concentration ≥200 mg/dL [11.1 mmol/L] or fasting plasma glucose ≥126 mg/dL [7.0 mmol/L] or 2-hour postload glucose ≥200 mg/dL [11.1 mmol/L] during an oral glucose tolerance test). We excluded patients on dialysis, and those with ST-segment–elevation myocardial infarction undergoing primary angioplasty (because they were unable to receive the study hydration protocol for at least 6 hours before the procedure). Women were excluded if they were pregnant, breastfeeding, or aged <45 years and did not use contraceptive methods.
discrete variables were evaluated by the χ² test or Fisher exact test. Continuous variables with skewed distributions were analyzed using the Wilcoxon rank-sum test. The results of comparisons of proportions are presented as relative risks and their respective 95% confidence intervals. Secondary outcomes evaluated 30 days after randomization were analyzed using nonadjusted Cox proportional hazards regression. The composite outcome death or need for dialysis was presented as Kaplan–Meier curves. Missing values were not imputed. Statistical analyses were performed using STATA/SE 10.0 (STATA Corp LP, College Station, TX).

Results

Study Participants
From the 2308 patients included in the ACT, 1395 had diabetes mellitus (100% of type 2 diabetes mellitus) and were considered for the present substudy. Of the included patients, 717 were allocated to acetylcysteine and 678 to placebo. We were unable to obtain a 48- to 96-hour follow-up serum creatinine from 15 of 717 patients in the acetylcysteine group (2.1%) and 11 of 678 patients in the placebo group (1.6%; P=0.51). There were no statistically significant differences in key baseline characteristics, such as age, previous renal failure or heart failure, between patients whose 48- to 96-hour creatinine was not determined versus those with serum creatinine determined (data not shown).

The baseline characteristics were well balanced between the groups (Table 1). More than a half of the patients had an estimated creatinine clearance and estimated glomerular filtration rate >60 mL/min (1 mL/s) and >30% of the sample were aged >70 years and was included during an acute coronary syndrome episode.

Compliance With Study Protocol and Characteristics of Angiography
From the included patients, 66.2% underwent diagnostic coronary angiographies, 28.0% were submitted to percutaneous coronary interventions, and 2.6% to peripheral vascular angiography (Table 2). Low osmolarity contrast media was the most common type of contrast used (73.3% of the cases). In about half of the patients, the volume of contrast administered was >60 mL/min (1 mL/s) and >30% of the sample were aged >70 years and was included during an acute coronary syndrome episode.
Table 2. Procedure Characteristic, Protocol Adequacy, and Hydration Scheme

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Acetylcysteine Group</th>
<th>Placebo Group</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Procedure, no. of patients/total no. (%)</td>
<td>(n=717)</td>
<td>(n=678)</td>
<td>0.797</td>
</tr>
<tr>
<td>Peripheral vascular angiography</td>
<td>19 (2.6)</td>
<td>18 (2.7)</td>
<td></td>
</tr>
<tr>
<td>Coronary diagnostic angiography</td>
<td>475 (66.2)</td>
<td>462 (68.1)</td>
<td></td>
</tr>
<tr>
<td>Percutaneous coronary intervention</td>
<td>211 (29.4)</td>
<td>190 (28.0)</td>
<td></td>
</tr>
<tr>
<td>Not submitted to angiography</td>
<td>12 (1.7)</td>
<td>8 (1.2)</td>
<td></td>
</tr>
<tr>
<td>Adherence to study drug, no. of patients/total no. (%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>First dose</td>
<td>709 (98.9)</td>
<td>674 (99.4)</td>
<td>0.288</td>
</tr>
<tr>
<td>Second dose</td>
<td>699 (97.5)</td>
<td>656 (96.8)</td>
<td>0.411</td>
</tr>
<tr>
<td>Third dose</td>
<td>693 (96.7)</td>
<td>650 (95.9)</td>
<td>0.441</td>
</tr>
<tr>
<td>Fourth dose</td>
<td>688 (96.0)</td>
<td>642 (94.7)</td>
<td>0.263</td>
</tr>
<tr>
<td>Hydration before procedure, no. of patients/total no. (%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NaCl or bicarbonate</td>
<td>699 (97.5)</td>
<td>669 (98.7)</td>
<td>0.109</td>
</tr>
<tr>
<td>NaCl 0.9%, 1 mL/kg per h for 6 h</td>
<td>338 (47.1)</td>
<td>317 (46.8)</td>
<td>0.885</td>
</tr>
<tr>
<td>NaCl 0.9%, any scheme</td>
<td>666 (92.9)</td>
<td>642 (94.7)</td>
<td>0.164</td>
</tr>
<tr>
<td>NaCl 0.45%</td>
<td>1 (0.1)</td>
<td>0 (0.0)</td>
<td>&gt;0.99*</td>
</tr>
<tr>
<td>Bicarbonate 0.9%</td>
<td>34 (4.7)</td>
<td>29 (4.3)</td>
<td>0.676</td>
</tr>
<tr>
<td>Volume of hydration before procedure, mL/kg per h</td>
<td>Median (interquartile range)</td>
<td>1.0 (1.0–1.5)</td>
<td>1.0 (1.0–1.6)</td>
</tr>
<tr>
<td>Total volume of hydration before procedure, mL</td>
<td>462 (384–588)</td>
<td>480 (408–588)</td>
<td>0.097</td>
</tr>
<tr>
<td>Duration of hydration before procedure, h</td>
<td>Median (interquartile range)</td>
<td>5 (3–11)</td>
<td>6 (3–11)</td>
</tr>
<tr>
<td>Hydration after procedure, no. of patients/total no. (%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NaCl or bicarbonate</td>
<td>699 (97.1)</td>
<td>661 (97.5)</td>
<td>0.638</td>
</tr>
<tr>
<td>NaCl 0.9%, 1 mL/kg per h for 6 h</td>
<td>372 (51.9)</td>
<td>373 (55.0)</td>
<td>0.241</td>
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<tr>
<td>NaCl 0.9%, any scheme</td>
<td>502 (70.0)</td>
<td>493 (72.7)</td>
<td>0.265</td>
</tr>
<tr>
<td>NaCl 0.45%</td>
<td>0 (0.0)</td>
<td>0 (0.0)</td>
<td>…</td>
</tr>
<tr>
<td>Bicarbonate 0.9%</td>
<td>205 (28.6)</td>
<td>187 (27.6)</td>
<td>0.675</td>
</tr>
<tr>
<td>Volume of hydration after procedure, mL/kg per h</td>
<td>Median (interquartile range)</td>
<td>1.0 (1.0–1.0)</td>
<td>1.0 (1.0–1.0)</td>
</tr>
<tr>
<td>Total volume of hydration after procedure, mL</td>
<td>450 (390–540)</td>
<td>456 (390–540)</td>
<td>0.718</td>
</tr>
<tr>
<td>Duration of hydration after procedure, h</td>
<td>Median (interquartile range)</td>
<td>6 (3–24)</td>
<td>6 (3–24)</td>
</tr>
<tr>
<td>Contrast type, n, %†</td>
<td></td>
<td></td>
<td>0.99</td>
</tr>
<tr>
<td>High osmolarity</td>
<td>171 (24.3)</td>
<td>162 (24.2)</td>
<td></td>
</tr>
<tr>
<td>Low osmolarity</td>
<td>517 (73.3)</td>
<td>492 (73.4)</td>
<td></td>
</tr>
<tr>
<td>Iso-osmolar</td>
<td>17 (2.4)</td>
<td>16 (2.4)</td>
<td></td>
</tr>
<tr>
<td>Contrast volume, mL</td>
<td>Median (interquartile range)</td>
<td>100 (70–130)</td>
<td>100 (70–130)</td>
</tr>
<tr>
<td>Additional angiography within 48–96 h after the first procedure</td>
<td>29 (4.0)</td>
<td>30 (4.4)</td>
<td>0.724</td>
</tr>
<tr>
<td>Timing of serum creatinine sampling after angiography‡</td>
<td></td>
<td></td>
<td>0.319</td>
</tr>
<tr>
<td>48 to ≤72 h</td>
<td>556 (79.7)</td>
<td>539 (81.8)</td>
<td></td>
</tr>
<tr>
<td>72 to 96 h</td>
<td>142 (20.3)</td>
<td>120 (18.2)</td>
<td></td>
</tr>
</tbody>
</table>

*Fisher exact test.
†Respectively, 705 and 670 patients were ultimately submitted to angiography in the acetylcysteine and placebo groups. These are the denominators for type of contrast.
‡Serum creatinine after angiography was available for 698 and 659 patients in the acetylcysteine and placebo groups, respectively.
Angiography. Ninety-eight percent of the patients received intravenous hydration before and 97.3% after the procedure. The median duration of hydration before procedure was 5 and 6 hours for the acetylcysteine and placebo groups, respectively. After angiography, the median duration was 5 hours for both the groups (Table 2).

The mean times between angiography and follow-up serum creatinine sampling were significantly different between the groups. For most patients (80%), serum creatinine was collected between 48 and 72 hours after angiography (Table 2).

End Points
The primary end point occurred in 97 of 702 patients (13.8%) in the acetylcysteine group and in 98 of 667 patients (14.7%) in the placebo group. Elevation ≥44.2 μmol/L (0.5 mg/dL) in creatinine after the procedure was similar between groups. The effect of acetylcysteine versus placebo on doubling of serum creatinine was not statistically significant (Table 3).

The incidence of the composite outcome death or need for dialysis at 30 days was 2.2% in the acetylcysteine group and 2.1% in the placebo group (Table 3). The incidence of the composite outcome death, need for dialysis, or doubling in serum creatinine, as well as the incidence of the individual components of this composite outcome, were not statistically different between the acetylcysteine and the placebo groups. Cardiovascular deaths at 30 days were similar between groups (Figures 1, 2, 3, and 4).

The effect of acetylcysteine on contrast-induced acute kidney injury was not modified by baseline glomerular filtration rate. In patients with diabetes mellitus with glomerular filtration rate ≤60 mL/kg per 1.73 m² the risk ratio was 0.99 (95% confidence interval, 0.56–1.74), whereas in patients with diabetes mellitus with glomerular filtration rate >60 mL/kg per 1.73 m² the risk ratio was 0.96 (95% confidence interval, 0.72–1.28), with P value for homogeneity of 0.93.

Discussion
In this substudy of the ACT, acetylcysteine did not reduce the incidence of contrast-induced acute kidney injury in patients with diabetes mellitus. Moreover, acetylcysteine did not show beneficial effects on other end points, such as all-cause

Figures

**Figure 1.** Probability of death or need for dialysis from the day of randomization (day 0) to day 30 among patients in the acetylcysteine and placebo groups.

**Figure 2.** Probability of cardiovascular deaths from the day of randomization (day 0) to day 30 among patients in the acetylcysteine and placebo groups.
mortality and need for dialysis at 30 days. Results were consistent even in the high-risk subgroup of patients with diabetes mellitus and low baseline glomerular filtration rate.

To our knowledge, this is the first large randomized clinical trial to include a sample composed exclusively of patients with diabetes mellitus. Nevertheless, our results are consistent with previous acetylcysteine trials that have included a large proportion of patients with diabetes mellitus. In this regard, the study by Azmus et al, \textsuperscript{20} randomized 397 patients (from which 50\% were patients with diabetes mellitus) to receive oral acetylcysteine (600 mg) or placebo and concluded that acetylcysteine was not effective as a prophylactic treatment against contrast nephropathy. According to the study of Webb et al, \textsuperscript{21} 35\% of the total sample (170 patients) was composed of patients with diabetes mellitus. The incidence of contrast-induced nephropathy was similar between the intervention (acetylcysteine 500 mg immediately before the procedure) and the control groups. Our findings are also in accordance to large observational studies. A recent publication investigated the outcomes associated with the use of acetylcysteine in the prevention of contrast-induced nephropathy.\textsuperscript{22} The authors did not find improvements in clinical outcomes and suggest that the use of acetylcysteine should be abandoned.

Our trial had strengths. It represents the largest trial that tested the effects of acetylcysteine for the prevention of contrast-induced acute kidney injury in patients with diabetes mellitus conducted to date. We sought to ensure adequate methodological quality by using concealed randomization; blinding patients, investigators, caregivers, and outcome assessors; and analyzing data according to the intention-to-treat principle. We tested a higher dose of acetylcysteine, because previous evidence suggested that a dose of 1200 mg twice daily may be superior to a dose of 600 mg twice daily.\textsuperscript{23} Moreover, we used different methods to guarantee data quality, including on-site monitoring, central statistical monitoring of the data, and data collection through an electronic data capture system.

Our trial had limitations that merit consideration. First, we used creatinine as a marker of kidney injury, but some recent publications suggest that newer markers such as cystatin C are more reliable for detecting contrast-induced acute kidney injury.\textsuperscript{24} Nevertheless, results based on creatinine measures were consistent with those observed for other clinical end points. Second, the median volume of contrast used was low (100 mL), and previous studies demonstrated an association between contrast volume and risk of contrast-induced acute kidney injury.\textsuperscript{2} Third, we did not collect data on urine output, or we guided hydration according to this variable. A previous trial suggests that hydration titrated according to urine flow rate may be somewhat effective to prevent contrast-induced nephropathy, although this observation is not based on the randomized comparison evaluated.\textsuperscript{25} Nevertheless, current guidelines recommend isotonic crystalloid (1.0–1.5 mL/kg per hour) for 3 to 12 hours before the procedure and continuing for 6 to 24 hours after the procedure, as we recommended in our study, but do not make any specific recommendation regarding urine flow rate–guided hydration.\textsuperscript{26} Also, although we followed a hydration regimen recommended in current guidelines, the total amount of saline administered was low (≈900 mL) compared with other trials in the field.\textsuperscript{23,25,27,28} It is possible that larger total amount of fluids are related to a more effective protection against contrast-induced acute kidney injury as suggested by the unpublished Prospective, Randomized Trial of Sliding-Scale Hydration for Prevention of Contrast Nephropathy (POSEIDON) trial.\textsuperscript{29} Fourth, we opted for having streamlined data collection forms, which limited our ability to provide some relevant clinical information, such as information about the use of insulin among patients with diabetes mellitus. Finally, it may be suggested that the duration of our treatment scheme (acetylcysteine every 12 hours, 2 doses before and 2 doses after angiography) was not long enough to prevent kidney injury.\textsuperscript{30} Nonetheless, we think that extending acetylcysteine therapy would not change the results of our trial because the peak of renal dysfunction occurs shortly after angiography (2–5 days), with fast normalization after it. Furthermore, acetylcysteine was administered for only up to 48 hours after angiography in previous trials that found a beneficial effect of the drug.\textsuperscript{31}

In conclusion, our trial demonstrated that acetylcysteine did not prevent acute kidney injury or other clinical outcomes in patients with diabetes mellitus undergoing intravascular angiographic procedures, and thus we do not recommend for this population. These findings have important implications.
for clinical practice and may prevent unnecessary procedure delays and health expenditures associated with the administration of acetylcysteine.

Acknowledgments

We are indebted to all the study coordinators, investigators, and patients who participated in the ACT.

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Disclosures

None.

References

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What is Known:

- Diabetes mellitus is an independent risk factor for contrast-induced acute kidney injury.
- The efficacy of acetylcysteine for preventing contrast-induced nephropathy has been evaluated in several small size trials with inconsistent results.

What this Article Adds:

- Acetylcysteine does not reduce the risk of contrast-induced acute kidney injury nor other clinically relevant outcomes in diabetic patients undergoing coronary and peripheral vascular angiography.