Contrast-induced acute kidney injury (CI-AKI) is a known complication of coronary angiography and intervention, which represents 12% of hospital-acquired acute renal injury.1 The incidence of CI-AKI varies according to patient characteristics, type of procedure, and the definition used. Early observations reported a general incidence of 14.5% and 50% incidence in high-risk patients.2,3 Over the past 2 decades, the incidence of CI-AKI has decreased because of improvement in preventive measures and quality of contrast media. More recent observations demonstrated a general incidence of 8.5% and 33% incidence in high-risk patients.4–6 The most important patient-related risk factors are preexisting renal impairment and diabetes mellitus, while the most important procedure-related risk factor is contrast volume.7,8 Generally, CI-AKI is rare when the contrast dose is kept <100 mL; however, in high-risk patients, even a contrast dose of <100 mL is associated with significant risk.9 For every 5 mL increase in contrast volume, the odds of developing CI-AKI increased by 44%.2 The risk of CI-AKI can be minimized by not exceeding 30 mL of contrast agent in diagnostic procedures and 100 mL for interventional procedures.2,9

Currently, the most effective preventive measures are hydration and minimizing the contrast volume.

**Background**—The incidence of contrast-induced acute kidney injury is strongly related to the amount of the given contrast. Our objectives were to evaluate the efficacy and safety of coronary sinus aspiration (CSA) procedure to reduce the volume of the given contrast and attenuate the risk of contrast-induced acute kidney injury.

**Methods and Results**—The study included 43 patients with type 2 diabetes mellitus and renal impairment (creatinine 1.5–3 mg/dL) who were candidates for coronary angiography. Eighteen patients were subjected to CSA procedure during coronary angiography (CSA group), and 25 patients served as a control group. Periprocedural standard care was given. In CSA group, the coronary sinus was cannulated via subclavian or femoral venous approaches, and aspiration was done directly from a transseptal sheath (8 patients) or through a balloon occlusion catheter placed through the sheath (10 patients) simultaneously during each coronary injection. Estimated volume of aspirated contrast was calculated based on the percentage reduction in hematocrit value of the aspirate in relation to the patient’s baseline hematocrit. Fraction of aspirated contrast was calculated by dividing estimated volume of aspirated contrast over the volume of injected contrast×100. Both study groups were matched in clinical and laboratory data, as well as volume of injected contrast. In CSA group, mean fraction of aspirated contrast was 39.35±10.47%. One patient in the CSA group, compared with 9 patients in the control group, developed contrast-induced acute kidney injury (P=0.028).

**Conclusions**—CSA during coronary angiography could effectively remove more than one third of the given contrast and may reduce the incidence of contrast-induced acute kidney injury in selected patients. *(Circ Cardiovasc Interv. 2017;10:e004348. DOI: 10.1161/CIRCINTERVENTIONS.116.004348.)*

**Key Words:** contrast-induced acute renal injury ■ contrast-induced nephropathy ■ coronary angiography ■ coronary sinus ■ coronary sinus aspiration

---

**Background**—The incidence of contrast-induced acute kidney injury is strongly related to the amount of the given contrast. Our objectives were to evaluate the efficacy and safety of coronary sinus aspiration (CSA) procedure to reduce the volume of the given contrast and attenuate the risk of contrast-induced acute kidney injury.

**Methods and Results**—The study included 43 patients with type 2 diabetes mellitus and renal impairment (creatinine 1.5–3 mg/dL) who were candidates for coronary angiography. Eighteen patients were subjected to CSA procedure during coronary angiography (CSA group), and 25 patients served as a control group. Periprocedural standard care was given. In CSA group, the coronary sinus was cannulated via subclavian or femoral venous approaches, and aspiration was done directly from a transseptal sheath (8 patients) or through a balloon occlusion catheter placed through the sheath (10 patients) simultaneously during each coronary injection. Estimated volume of aspirated contrast was calculated based on the percentage reduction in hematocrit value of the aspirate in relation to the patient’s baseline hematocrit. Fraction of aspirated contrast was calculated by dividing estimated volume of aspirated contrast over the volume of injected contrast×100. Both study groups were matched in clinical and laboratory data, as well as volume of injected contrast. In CSA group, mean fraction of aspirated contrast was 39.35±10.47%. One patient in the CSA group, compared with 9 patients in the control group, developed contrast-induced acute kidney injury (P=0.028).

**Conclusions**—CSA during coronary angiography could effectively remove more than one third of the given contrast and may reduce the incidence of contrast-induced acute kidney injury in selected patients. *(Circ Cardiovasc Interv. 2017;10:e004348. DOI: 10.1161/CIRCINTERVENTIONS.116.004348.)*

**Key Words:** contrast-induced acute renal injury ■ contrast-induced nephropathy ■ coronary angiography ■ coronary sinus ■ coronary sinus aspiration

---

**Background**—The incidence of contrast-induced acute kidney injury is strongly related to the amount of the given contrast. Our objectives were to evaluate the efficacy and safety of coronary sinus aspiration (CSA) procedure to reduce the volume of the given contrast and attenuate the risk of contrast-induced acute kidney injury.

**Methods and Results**—The study included 43 patients with type 2 diabetes mellitus and renal impairment (creatinine 1.5–3 mg/dL) who were candidates for coronary angiography. Eighteen patients were subjected to CSA procedure during coronary angiography (CSA group), and 25 patients served as a control group. Periprocedural standard care was given. In CSA group, the coronary sinus was cannulated via subclavian or femoral venous approaches, and aspiration was done directly from a transseptal sheath (8 patients) or through a balloon occlusion catheter placed through the sheath (10 patients) simultaneously during each coronary injection. Estimated volume of aspirated contrast was calculated based on the percentage reduction in hematocrit value of the aspirate in relation to the patient’s baseline hematocrit. Fraction of aspirated contrast was calculated by dividing estimated volume of aspirated contrast over the volume of injected contrast×100. Both study groups were matched in clinical and laboratory data, as well as volume of injected contrast. In CSA group, mean fraction of aspirated contrast was 39.35±10.47%. One patient in the CSA group, compared with 9 patients in the control group, developed contrast-induced acute kidney injury (P=0.028).

**Conclusions**—CSA during coronary angiography could effectively remove more than one third of the given contrast and may reduce the incidence of contrast-induced acute kidney injury in selected patients. *(Circ Cardiovasc Interv. 2017;10:e004348. DOI: 10.1161/CIRCINTERVENTIONS.116.004348.)*

**Key Words:** contrast-induced acute renal injury ■ contrast-induced nephropathy ■ coronary angiography ■ coronary sinus ■ coronary sinus aspiration

---

Contrast-induced acute kidney injury (CI-AKI) is a known complication of coronary angiography and intervention, which represents 12% of hospital-acquired acute renal injury.1 The incidence of CI-AKI varies according to patient characteristics, type of procedure, and the definition used. Early observations reported a general incidence of 14.5% and 50% incidence in high-risk patients.2,3 Over the past 2 decades, the incidence of CI-AKI has decreased because of improvement in preventive measures and quality of contrast media. More recent observations demonstrated a general incidence of 8.5% and 33% incidence in high-risk patients.4–6 The most important patient-related risk factors are preexisting renal impairment and diabetes mellitus, while the most important procedure-related risk factor is contrast volume.7,8 Generally, CI-AKI is rare when the contrast dose is kept <100 mL; however, in high-risk patients, even a contrast dose of <100 mL is associated with significant risk.9 For every 5 mL increase in contrast volume, the odds of developing CI-AKI increased by 44%.2 The risk of CI-AKI can be minimized by not exceeding 30 mL of contrast agent in diagnostic procedures and 100 mL for interventional procedures.2,9

Currently, the most effective preventive measures are hydration and minimizing the contrast volume.

**See Editorial by Solomon and Dauerman**

Removal of the contrast from the coronary sinus (CS) during coronary angiography in high-risk patients was previously studied.10,11 Danenberg et al10 attempted to remove the contrast from CS in 7 patients with renal impairment using a balloon occluding catheter. However, they failed to deploy the catheter into the CS in 4 patients, with frequent sliding of the balloon outside the CS, probably because of lack of support by a sheath. Duffy et al11 succeeded to attenuate the risk of CI-AKI in predisposed patients with a specially designed CS aspiration catheter and support device equipped with a vacuum-driven aspiration unit in 26 patients in comparison to a control group. However, the unavailability of such dedicated system and the bulky equipment used would probably hinder the practicality of such technique. Therefore, the study of Danenberg et al10 seemed to be more simple and reasonable if it could be modified.
WHAT IS KNOWN

• Contrast-induced acute kidney injury is strongly related to the volume of contrast given during coronary angiography.

WHAT THE STUDY ADDS

• Owing to the acquired experience in manipulating the coronary sinus over the past 2 decades, coronary sinus aspiration during coronary angiography may be an attractive approach to remove the contrast.
• The present study provides a simple technique to aspirate the contrast from coronary sinus during coronary angiography concomitantly with each contrast injection, without the need for specialized equipment.
• Coronary sinus aspiration during coronary angiography could effectively remove more than a third of the given contrast and could attenuate the risk of contrast-induced acute kidney injury in high-risk patients compared with a matched control group.

Methods

The study was approved by the ethical committee of the Faculty of Medicine, Ain Shams University, Cairo, Egypt. In a prospective design, the study included 43 patients with type 2 diabetes mellitus indicated for coronary angiography who had baseline serum creatinine levels of 1.5 to 3 mg/dL during the period from January 2014 to March 2016. Patients were divided into CS aspiration (CSA) group (18 consecutive patients) who were subjected to CSA procedure during coronary angiography/percutaneous coronary intervention (PCI) and control group (25 patients) who underwent coronary angiography/PCI only. Patients with acute ST-segment-elevation myocardial infarction or other emergency conditions (such as hemodynamic instability complicating acute ischemia), congestive heart failure, hemoglobin level <8 g %, age >75 years, hyperkalemia (serum K+ >5.3 mEq/L), obstructive uropathy, creatinine clearance (CrCl) <25 mL/min, and patients with single functioning kidney were nonincluded. Twelve lead surface ECG, transthoracic echocardiogram, and noninvasive stress test (if any) were examined to assess the indication for angiography. Laboratory tests, including serum creatinine, serum potassium, hemoglobin level, and hematocrit (Hct) value were done by standard methods using commercially available kits. CrCl was measured using Cockcroft–Gault formula\(^1\)\(^2\) as follow:

\[
\text{CrCl} = \frac{[140 - \text{age (years)}] \times \text{weight (kg)} \times 0.85}{[72 \times \text{serum creatinine (mg/dL)}]}.
\]

In all patients, serum creatinine level was measured daily following the procedure till the third postprocedural day. CrCl was calculated and serum potassium was measured at time of peak serum creatinine level.

A written consent was taken explaining the benefits and possible risks of each of the angiographic procedure and the CSA procedure with the possibility of failure of the technique and the need for hemodialysis.

Periprocedural Care

In all patients, intravenous normal saline (1–1.5 mL/kg per hour) was initiated 6 hours (for hospitalized patients) and 3 hours (for outpatients) before the procedure and continued for 24 hours. N-acetylcysteine was given to all patients in a dose of 600 mg twice daily for 24 hours before and on the day of the procedure. Potentially nephrotoxic drugs (such as nonsteroidal anti-inflammatory drugs and aminoglycosides) were discontinued 24 hours before the procedure. Metformin was stopped at the time of the procedure and resumed 48 hours later if kidney function remained normal.

Coronary Sinus Cannulation

In CSA group, CS cannulation was done after introduction of right femoral arterial sheath and before coronary arteriography. CS was accessed via left subclavian vein or right femoral vein. An introducer sheath was inserted, then a 0.032-inch J-wire was introduced to the right atrium, and the sheath was removed. A transseptal sheath (Mullins, Medtronic, and St Jude Medical; 8 or 8.5 F) was used to cannulate the CS. The sheath and dilator were introduced over the wire. A 40° left anterior oblique projection was used to cannulate the CS (Figure 1). If the CS could not be cannulated directly by the sheath, a conventional (nondeflectable) decapolar (or quadripolar) CS catheter was introduced into the sheath and advanced into the CS to help cannulation (Figure 1A). A small amount of contrast (2 to 3 mL) was injected to confirm CS cannulation (Figure 1B). CS cannulation time was measured from venous puncture to CS angiography. Fluoroscopy time during CS cannulation was also recorded.

Coronary Angiography and Intervention

Coronary angiography was done by standard technique via right femoral approach. A 100% (undiluted) nonionic contrast (iopromide) was manually injected and attempted to be limited as little as possible, especially during injection of the right coronary artery (RCA). Contrast dose was limited to 5 mL/kg body weight if not exceeding 300 mL divided by serum creatinine (mg/dL).\(^3\)\(^4\) The total volume of injected contrast (VIC) was recorded.

Coronary Sinus Aspiration

In CSA group, a balloon-tipped catheter (7 F, single lumen; Arrow Int, Reading, PA) was introduced over a percutaneous transcatheter coronary angioplasty 300 cm extrasupport wire to the CS through the sheath (Figure 2). Balloon was inflated by air to occlude the proximal CS before each coronary injection, then deflated after CSA. In selected cases, the sheath was seated inside CS and engaged into its proximal or middle third for direct aspiration without using balloon-tipped catheter (Figure 1B). Choice of CSA whether by balloon-tipped catheter or directly by the sheath was determined by the caliber of CS in relation to the sheath diameter. The former was done in case of large CS, whereas the latter was done in case of small CS diameter (<1.5 the sheath diameter) at its proximal or middle third.

With each contrast injection, CSA was done simultaneously using a 20 mL syringe, with continued fluoroscopy to show the appearance of contrast in CS and then clearance by aspiration. Because RCA is drained mainly via non-CS veins, and owing to the relatively small amount of contrast used, CSA was not planned to be done during RCA injection unless dominant, occluded left anterior descending with retrograde filling from the RCA, or being a mega vessel.

Figure 1. Coronary sinus cannulation in 40° left anterior oblique (LAO) projection. A. Cannulation using decapolar catheter inside the sheath through left subclavian approach. B. Coronary sinus could be directly accessed by the sheath and engaged in its middle third for direct aspiration. CS indicates coronary sinus; DC, decapolar catheter; and Sh, sheath.
Time from injection to contrast clearance from CS (time to contrast clearance from CS) was recorded (by timer inside Windows Media Player for Windows 7 after conversion of angiography DICOM files to Windows Media Player files) from the beginning of injection till the complete disappearance of contrast from CS.

Syringe containing the CS aspirate was put under fluoroscopy beside a syringe containing pure CS blood to ascertain the presence of contrast in CS aspirate. The volume of CS aspirate during each injection and the totally collected CS aspirate were measured. Volume of CS aspirate per injection was measured by dividing the total CS aspirate over the number of aspirations. Sample from the collected CS aspirate was taken to measure Hct value. At the end of procedure, venous sheath was removed with gentle compression and dressing. Any procedure-related complications were recorded. CI-AKI was defined as an increase in serum creatinine by ≥25% or ≥0.5 mg/dL within 3 days after the procedure in the absence of other suspected causes of acute renal injury.15

Calculation of the Volume of Aspirated Contrast

CS aspirate consisted of blood and contrast, replacing some of the blood drained from arterial side. To calculate the volume of contrast aspirated from the CS, we compared Hct value of the patient’s blood with that of the CS aspirate. The reduction of Hct value (Hct value of patient’s blood–Hct value of CS aspirate) expressed the added contrast in the CS aspirate. By dividing reduction in Hct value by the Hct of patient’s blood, we obtained the percentage reduction in Hct value, which when multiplied by the volume of CS aspirate can give the absolute volume of aspirated contrast (Figure 3). Similar method was previously used to calculate normovolemic intraoperative blood loss using percentage reduction in Hct after hemodilution with intravenous fluids.16,17 We applied the same formula to the CS aspirate to determine the amount of blood loss from the sample, which corresponds to the volume of added contrast.

Estimated volume of aspirated contrast (EVAC) was calculated as follow:

$$\text{EVAC} = \frac{\text{Hct2} - \text{Hct1}}{\text{Hct1}} \times \text{VCSA}$$

where EVAC is the estimated volume of aspirated contrast; Hct2, hematocrit value of CS aspirate; Hct1, baseline hematocrit value of patient’s blood; and VCSA, volume of CS aspirate.

Fraction of aspirated contrast was then calculated as follow:

$$\text{FAC} (%) = \frac{\text{EVAC}}{\text{VIC}} \times 100$$

where FAC is the fraction of aspirated contrast; EVAC, estimated volume of aspirated contrast; and VIC, volume of injected contrast.

Figure 2. A, Cannulation of CS by transseptal sheath through femoral approach with percutaneous transcatheter coronary angioplasty wire inside the CS (in a patient with dual chamber pacemaker). B, Introduction of balloon-tipped catheter over the wire in the same patient. C, Inflation of the balloon to occlude the proximal CS with injection of contrast to ascertain proper CS occlusion in the same patient. D, Same steps applied through subclavian approach. BTC indicates balloon-tipped catheter; CS, coronary sinus; Sh, sheath; and W, wire.

Figure 3. An example of using percentage reduction in Hct value for the calculation of the volume of added contrast. To the left is a 10 mL blood sample with Hct value of 40% (packed cell volume = 4 mL). To the right is a new blood sample after adding 2 mL of contrast. Hct value decreased to 33.3%, and the new sample volume is 12 mL. Percentage reduction in Hct value = $40−33.3/40=0.167$. The volume of added contrast = percentage reduction in Hct×volume of new sample = $0.167 \times 12 = 2$ mL. Hct indicates hematocrit value; P, plasma; PCV, packed cell volume; and P+C, plasma+contrast.
Statistical Analysis

Statistical Package for Social Sciences (SPSS, Inc, version 21, Chicago, IL) was used. Continuous data were expressed as mean±standard deviation or median (interquartile range) according to data distribution. The D’Agostino–Pearson test was used to ascertain normality of data, then paired $t$ test or Wilcoxon signed-rank test was used to compare preprocedural and postprocedural data. Unpaired $t$ test or Mann–Whitney test was used to compare independent samples. Multivariate logistic regression analysis was done with CI-AKI as an outcome, and variables with $P$ value <0.1 on univariate analysis or clinically relevant ones were included as independent variables. $P$ value was considered significant if <0.05.

Results

Baseline Characteristics

Baseline characteristics are shown in Table 1. There were no significant differences between CSA group and the control group regarding age, sex, risk factors, indication of coronary angiography, baseline laboratory data, and periprocedural hydration volume received.

CSA Procedure

Procedural details of CSA are shown in Table 2. CS cannulation and aspiration was successful in all patients, with no procedural failures till the end of the angiographic study. Subclavian access was done in 8 patients, while femoral access was done in 10 patients. Direct sheath cannulation could be done in 6 patients, while in 12 patients, a CS decapolar or quadripolar catheter was introduced inside the sheath to help cannulation. Aspiration from balloon-tipped catheter was done in 10 patients (Figure 4), while in 8 patients, aspiration was done directly from the sheath (Figure 5A through 5C).

Under fluoroscopy, syringe containing the CS aspirate was found to be darker than that containing pure CS blood (Figure 5D) in all cases after aspiration.

CS cannulation time was 19.27±3.54 minutes, with fluoroscopy time of 7.44±2.81 minutes. In the last 9 cases (cases no 10–18), CS cannulation time was shorter than that in the first 9 cases (17.11±1.61 versus 21.44±3.67 minutes; $P=0.005$). CS cannulation fluoroscopy time was also shorter in the last 9 cases than that in the first 9 cases (5.11±0.78 versus 9.77±1.98; $P<0.0001$).

Time to contrast clearance from CS was 11.3±0.74 seconds. Cases with balloon occlusion had longer time than that in cases with direct sheath aspiration (11.71±0.59 versus 10.8±0.6; $P=0.006$). EVAC was 34.06±16.35 mL, which constituted 39.35±10.47% of the VIC. In cases with balloon occlusion, fraction of aspirated contrast was not significantly different from that in cases with direct sheath aspiration (38.92±10.24% versus 39.89±11.43%; $P=0.85$).

Coronary Angiography/PCI and Postprocedural Outcome

There were no significant differences between CSA group and control group in type of coronary procedure and VIC (Table 3). Postprocedural peak serum creatinine was found to be significantly higher in the control group ($P=0.001$). Percentage and

Table 1. Baseline Characteristics

<table>
<thead>
<tr>
<th></th>
<th>All (n=43)</th>
<th>CSA Group (n=18)</th>
<th>Control Group (n=25)</th>
<th>$P$ Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, y</td>
<td>62.23±6.08</td>
<td>62.16±5.96</td>
<td>62.28±6.28</td>
<td>0.95</td>
</tr>
<tr>
<td>Sex (males, females), n</td>
<td>32, 11</td>
<td>13, 5</td>
<td>19, 6</td>
<td>1.00</td>
</tr>
<tr>
<td>Risk factors, n</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Smoking</td>
<td>18</td>
<td>9</td>
<td>9</td>
<td>0.36</td>
</tr>
<tr>
<td>HTN</td>
<td>31</td>
<td>15</td>
<td>16</td>
<td>0.16</td>
</tr>
<tr>
<td>Dyslipidemia</td>
<td>25</td>
<td>8</td>
<td>17</td>
<td>0.12</td>
</tr>
<tr>
<td>Indication of coronary angiography, n</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Anterior STEMI</td>
<td>4</td>
<td>2</td>
<td>2</td>
<td>1.00</td>
</tr>
<tr>
<td>Inferior STEMI</td>
<td>3</td>
<td>1</td>
<td>2</td>
<td>1.00</td>
</tr>
<tr>
<td>ACS</td>
<td>18</td>
<td>8</td>
<td>10</td>
<td>0.77</td>
</tr>
<tr>
<td>SA</td>
<td>18</td>
<td>7</td>
<td>11</td>
<td>0.73</td>
</tr>
<tr>
<td>LVEF, %</td>
<td>58.16±9.13</td>
<td>57.11±9.85</td>
<td>58.92±8.7</td>
<td>0.52</td>
</tr>
<tr>
<td>Creatinine, mg/dL</td>
<td>2.06±0.4; median 2 (1.8–2.2)*</td>
<td>1.98±0.43; median 1.9 (1.6–2.1)</td>
<td>2.13±0.38; median 2.1 (1.8–2.55)</td>
<td>0.24</td>
</tr>
<tr>
<td>CrCI, mL/min</td>
<td>43.32±10.78</td>
<td>45.62±12.88</td>
<td>41.69±8.91</td>
<td>0.24</td>
</tr>
<tr>
<td>K+, mEq/L</td>
<td>4.17±0.45</td>
<td>4.06±0.4</td>
<td>4.26±0.46</td>
<td>0.14</td>
</tr>
<tr>
<td>Hb, g %</td>
<td>11.44±1.34</td>
<td>11.1±1.33</td>
<td>11.69±1.32</td>
<td>0.15</td>
</tr>
<tr>
<td>Periopercudural hydration volume, mL</td>
<td>2725.58±420.37</td>
<td>2694.44±434.5</td>
<td>2748±417.45</td>
<td>0.68</td>
</tr>
</tbody>
</table>

ACS indicates acute coronary syndrome; CrCI, creatinine clearance; CSA, coronary sinus aspiration; Hb, hemoglobin; HTN, hypertension; LVEF, left ventricular ejection fraction; SA, stable angina; and STEMI, ST-segment–elevation myocardial infarction.

*Between brackets is the interquartile range.
absolute changes in serum creatinine were significantly higher in the control group ($P=0.032$ and 0.024, respectively). Postprocedural CrCl was significantly lower in the control group ($P=0.044$). There was no significant change in postprocedural serum K+ level.

Number of patients who developed CI-AKI was 1 (5.55%) in CSA group versus 9 (36%) in the control group ($P=0.028$). Among patients with CI-AKI, only 1 patient (belonging to the control group) underwent hemodialysis, while other patients were managed conservatively until spontaneous recovery. There were no vascular or mechanical complications or deaths among the whole study sample. Postprocedural hemoglobin in CSA group was lower than that in the control group but did not reach statistical significance ($P=0.06$). Multivariate analysis including baseline serum creatinine, VIC, and CSA as independent variables with CI-AKI as an outcome revealed that lack of CSA was the only independent variable associated with CI-AKI (odds ratio 9.26; confidence interval 1.03–83.26; $P=0.047$).

## Discussion

### Main Findings

In the present study, our objectives were to evaluate the efficacy and safety of CSA during coronary angiography in patients with preexisting renal impairment and type 2 diabetes mellitus aiming at the removal of a fraction of the given contrast before reaching the systemic circulation in an attempt to reduce the risk of CI-AKI. The current study demonstrated that manual removal of contrast from the CS was feasible, safe, and could be done using commonly available equipment in catheterization laboratories. By a simple technique, we could remove 39.35±10.47% of the given contrast.

The concept of contrast removal after injection in high-risk patients has been growing over the past and current decades. There have been 2 approaches: the systemic and the CS approaches. The systemic removal of contrast agent by hemodialysis starting immediately after the administration of contrast agent has shown no net benefit. Periprocedural hemofiltration appeared to be more effective in preventing CI-AKI after PCI in high-risk patients; however, this would be at the expense of the possible physical and psychological hazards in addition to the cost of the procedure. Furthermore, long-term benefit was manifest only in those with baseline serum creatinine $\geq$4 mg/dL.

CS seemed to be an attractive approach for contrast removal. However, this was before the era of advances in cardiac resynchronization therapy and ablation techniques targeting the CS,

### Table 2. Procedure Details Among Coronary Sinus Aspiration Group

<table>
<thead>
<tr>
<th></th>
<th>n=18</th>
</tr>
</thead>
<tbody>
<tr>
<td>CS access, n</td>
<td></td>
</tr>
<tr>
<td>Subclavian</td>
<td>8</td>
</tr>
<tr>
<td>Femoral</td>
<td>10</td>
</tr>
<tr>
<td>CS cannulation, n</td>
<td></td>
</tr>
<tr>
<td>Direct sheath cannulation</td>
<td>6</td>
</tr>
<tr>
<td>Decapolar/quadripolar catheter</td>
<td>12</td>
</tr>
<tr>
<td>CS aspiration, n</td>
<td></td>
</tr>
<tr>
<td>Balloon-tipped catheter</td>
<td>10</td>
</tr>
<tr>
<td>Direct sheath aspiration</td>
<td>8</td>
</tr>
<tr>
<td>CS aspiration during RCA injection, n</td>
<td>6</td>
</tr>
<tr>
<td>CS cannulation time, min</td>
<td>19.27±3.54</td>
</tr>
<tr>
<td>CS cannulation fluoroscopy time, min</td>
<td>7.44±2.81</td>
</tr>
<tr>
<td>Time to clearance of contrast from CS, s</td>
<td>11.3±0.74</td>
</tr>
<tr>
<td>VIC, mL</td>
<td></td>
</tr>
<tr>
<td>82.9±40.16 (median 70)</td>
<td></td>
</tr>
<tr>
<td>VCSA, mL</td>
<td></td>
</tr>
<tr>
<td>122.77±54.53</td>
<td></td>
</tr>
<tr>
<td>Volume of CS aspirate per injection, mL</td>
<td>16.6±5.23</td>
</tr>
<tr>
<td>EVAC, mL</td>
<td></td>
</tr>
<tr>
<td>34.06±16.35</td>
<td></td>
</tr>
<tr>
<td>FAC, %</td>
<td></td>
</tr>
<tr>
<td>39.35±10.47</td>
<td></td>
</tr>
</tbody>
</table>

CS indicates coronary sinus; EVAC, estimated volume of aspirated contrast; FAC, fraction of aspirated contrast; RCA, right coronary artery; VCSA, volume of coronary sinus aspirate; and VIC, volume of injected contrast.

---

**Figure 4.** Serial images showing CS balloon occlusion and aspiration of contrast during coronary angiography through subclavian approach (upper) and femoral approach (lower). A and D, Coronary injection after balloon occlusion of proximal coronary sinus. B and E, Contrast retention in coronary sinus during aspiration. C and F, Clearance of contrast from coronary sinus. CS indicates coronary sinus; and Sh, sheath.
which built a large experience in handling the CS. Approaches using the CS have been started in animal models. Using technologies other than manual aspiration, Michishita and Fujii evaluated the efficacy and safety of an extracorporeal adsorbing column equipped with a roller pump to selectively remove the contrast agent from the CS during coronary angiography in swine models using a specially designed 8 F CS catheter. The procedure was more or less similar to hemofiltration, with the advantages of selectivity to CS blood and selectivity to contrast filtration. Although the technique could remove 72% of the contrast agent, it was done during contrast infusion rather than injection in coronary arteries, rendering its possible use in humans inapplicable. Chang et al used a 10 F CS catheter equipped with fiberoptic sensor, which could automatically detect and remove the contrast from the CS in canine models and achieved a 59.3±11% contrast removal rate.

Early human experience in contrast aspiration from the CS showed limited success. Danenberg et al attempted to remove the contrast from CS during coronary angiography in 7 patients with preexisting renal impairment using the balloon occlusion technique. In the 3 successful cases, they could effectively remove 44±8% of the given contrast. Using a device-based technology, Duffy et al tested the effectiveness of a purpose-designed 11 F CSA catheter and CS support device via a 14 F internal jugular venous sheath equipped with a vacuum-driven aspiration unit in 26 patients. They could remove 32±3% (range 6%–64%) of the given contrast during coronary angiography, with favorable outcome in respect to renal function in comparison to a control group. However, the lack of such equipment would hinder its application in common practice.

Procedural Details
Although not being designed for the CS, the traseptal sheath was safe and effective in CS cannulation, support of the

---

**Table 3. Coronary Procedure and Postprocedural Data**

<table>
<thead>
<tr>
<th></th>
<th>All (n=43)</th>
<th>CSA Group (n=18)</th>
<th>Control Group (n=25)</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coronary procedure, n</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diagnostic</td>
<td>27</td>
<td>12</td>
<td>15</td>
<td>0.65</td>
</tr>
<tr>
<td>Intervention</td>
<td>16</td>
<td>6</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>Single vessel intervention</td>
<td>10</td>
<td>3</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>Multivessel intervention</td>
<td>6</td>
<td>3</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>VIC, mL</td>
<td>82.9±40.16; median 70 (60–100)*</td>
<td>88.6±42.69; median 70 (57.5–125)</td>
<td>78.8±38.6; median 70 (60–92.5)</td>
<td>0.57</td>
</tr>
<tr>
<td>Postprocedural peak serum creatinine, mg/dL</td>
<td>2.3±0.57; median 2.2 (2–2.6)</td>
<td>2.01±0.41; median 1.95 (1.3–2.2)</td>
<td>2.5±0.58; median 2.3 (2.1–2.75)</td>
<td>0.001</td>
</tr>
<tr>
<td>Percentage change in serum creatinine, %</td>
<td>11.77±19.61; median 11.11 (−5 to 23.75)</td>
<td>3.03±16.24; median 6.72 (−11.1 to 15.78)</td>
<td>18.06±19.69; median 14.28 (8.14–27.6)</td>
<td>0.032</td>
</tr>
<tr>
<td>Absolute change in serum creatinine, mg/dL</td>
<td>0.23±0.42; median 0.2 (−0.1 to 0.37)</td>
<td>0.03±0.3; median 0.15 (−0.2 to 0.3)</td>
<td>0.37±0.44; median 0.3 (0.1–0.6)</td>
<td>0.024</td>
</tr>
<tr>
<td>Postprocedural CrCl, mL/min†</td>
<td>39.64±12.06; median 39.3 (33.3–44.8)</td>
<td>44.62±14.72; median 43.6 (35.2–46.2)</td>
<td>36.05±8.85; median 36 (28.3–42.85)</td>
<td>0.044</td>
</tr>
<tr>
<td>Postprocedural K+, mEq/L†</td>
<td>4.33±0.48</td>
<td>4.27±0.45</td>
<td>4.38±0.5</td>
<td>0.48</td>
</tr>
<tr>
<td>CIN, n (%)</td>
<td>10 (23.25)</td>
<td>1 (5.55)</td>
<td>9 (36)</td>
<td>0.028</td>
</tr>
<tr>
<td>Postprocedural Hb, g %</td>
<td>11.3±1.34</td>
<td>10.85±1.3</td>
<td>11.62±1.3</td>
<td>0.06</td>
</tr>
</tbody>
</table>

CIN indicates contrast-induced nephropathy; CrCl, creatinine clearance; CSA, coronary sinus aspiration; Hb, hemoglobin; and VIC, volume of injected contrast.

*Between brackets is the interquartile range.
†At time of peak serum creatinine level.
balloon-tipped catheter, and in direct aspiration in the present study. The choice of truCephal sheath was based on its favorable curves that would fit different CS takeoff angles and the possibility to rotate and manipulate with or without support by the dilator (being short of the sheath tip). Because it is designed for left atrial access, it should be safe during manipulation inside both atria. To get familiar with sheath manipulation to capture the CS ostium, the CS cannulation time was longer in the early than in the last cases in our series. CS cannulation time was 19.27±3.54 minutes, which might be longer than that in Duffy et al\textsuperscript{11} study (11.1±9.3 minutes), likely because they used custom-designed equipment. The cause of failure of Danenberg et al\textsuperscript{10} to stabilize the balloon-tipped catheter in the CS is probably the lack of support by a sheath. Unless supported, the inflation of the balloon-tipped catheter may lead to either sliding out of the CS or a subocclusive inflation. Compared with other studies, we used less bulky equipments. The sheath was 8 to 8.5 F in our series, while other studies used 10 F catheter, 11 F catheter, and 14 F sheath.\textsuperscript{11,21}

Unless dominant, we did not aspirate from CS during RCA injection because the RCA is mainly drained by the anterior cardiac veins and Thesbian system rather than the CS.\textsuperscript{19} This fact, which was probably missed in other studies, may save some of the procedural and fluoroscopy times, as well as patients’ blood. Volume of CS aspirate per injection in our series was 16.6±3.23 mL, which was close to that in Danenberg et al’s\textsuperscript{10} study (12–16 mL).

Time to contrast clearance from CS was 11.3±0.74 seconds in current study. Cases with balloon occlusion had longer time than that in cases with direct sheath aspiration (P=0.006). This might be because of the wider caliber of the sheath with faster aspiration and less probability of suction collapse or facing a wall by the aspirating tip. Although less occlusive than the balloon-tipped catheter, sheath allowed for stronger negative suction, which might decrease the surrounding leak. This may account for the similar fractions of aspirated contrast in both balloon occlusion and direct sheath aspiration methods in our study (P=0.85). The choice between either methods was determined by the CS caliber in relation to sheath. In patients with dilated hearts, balloon occlusion method was more antici-pated. It also should be taken into consideration that the CS carries 70% to 80% of the venous drainage in normal conditions,\textsuperscript{22} but not in case of increased CS pressure, in which some blood may bypass the CS through the low resistance Thesbian system to the ventricular cavity.\textsuperscript{23} This would give a theoretical advantage to the direct sheath aspiration method over the balloon occlusion method, which needs to be verified by a larger comparative study.

We could remove 39.35±10.47% of the given contrast. This was more or less close to the fractions removed by Danenberg et al\textsuperscript{10} (44±8%) and Duffy et al\textsuperscript{11} (32±3%), but seemed to be less than that in Chang et al’s\textsuperscript{23} (59±3±11%) study. This may be explained by anatomic considerations, method of measuring the volume of the removed contrast, or the small study samples.

There was a special concern regarding the effect of CS occlusion on coronary arterial flow in such ischemic patients. It was previously reported that an increased CS pressure may decrease coronary flow.\textsuperscript{24} However, the reactive hyperemia after balloon deflation may enhance the microcirculation as demonstrated by the favorable results of pressure-controlled intermittent CS occlusion in several studies.\textsuperscript{25} Furthermore, the prolonged coronary artery transit time during angiography under CS occlusion may demand less amount of contrast required for proper imaging as shown by Danenberg et al.\textsuperscript{10}

**Clinical Outcome**

Out of 18 high-risk patients subjected to CSA, we encountered one case of CI-AKI (5.55%) compared with 9 (36%) out of 25 control subjects matched in clinical characteristics and VVC. Similarly, Duffy et al\textsuperscript{11} reported significant renal protection with CS intervention. The incidence of CI-AKI was as much as 50% in diabetic azotemic patients, with baseline creatinine exceeding 3 mg/dL.\textsuperscript{3} To be taken into consideration, we selected patients with diabetes mellitus and baseline creatinine of 1.5 to 3 mg/dL, the range that would probably accentuate the benefit of CSA procedure, below or above which the benefit might be either diluted or overwhelmed, respectively. Because the technique adds time and maneuvering to the angiographic procedure, it would be best used in a population with similar degree of risk, keeping into consideration that adequate hydration is still the standard preventive measure, regardless of any adjunctive procedures to prevent CI-AKI.\textsuperscript{26,27}

Larger studies are needed to ascertain the reproducibility of our findings.

There was a slight decrease in postprocedural hemoglobin in CSA group compared with control group. This can be subsequently managed without the need of sophisticated technologies to selectively remove the contrast out of the CS blood. Overall, we propose a simple and cheap technique to withdraw more than a third of the given contrast in high-risk patients without the need of dedicated equipment or advanced technologies. This may attenuate the fear from CI-AKI, which has deprived many of such patients from angiography. The novelty concerns in the current study could be (1) the rebirth of the concept of contrast retrieval from the CS, which was encouraged by the growing experience in CS manipulation and the decreased fear from reducing coronary arterial flow during CS balloon occlusion after the emergence of pressure-controlled intermittent CS occlusion technique; (2) the use of sheath to support the balloon catheter; (3) the selection and taming of transseptal sheath for our purpose; (4) omitting aspiration during nondominant RCA injection; (5) the direct sheath aspiration in selected cases; and (6) the simplicity of the technique and use of available equipment.

Limitations of the current study may include the following: (1) The small number of CSA group. However, in comparison to previous studies and in respect to the novelty issues of such technique, the number might be reasonable. Owing to the small number of cases with CI-AKI, multivariate logistic regression analysis should be interpreted with caution as reflected in the wide range of confidence interval (1.03–83). (2) The narrow range of baseline serum creatinine suitable for such intervention and lack of randomization. (3) The possible risk of CS dissection or pneumothorax (in case of subclavian approach), although not encountered in the present study. (4)
The need for a second interventionalist who is experienced in CS manipulation. (5) It cannot be applied in patients with planned PCI to a nondominant RCA or in primary PCI procedures.

Conclusions
CSA during coronary angiography may be effective in the removal of reasonable amount of contrast and in attenuating procedures.

Disclosures
None.

References
Efficacy and Safety of Coronary Sinus Aspiration During Coronary Angiography to Attenuate the Risk of Contrast-Induced Acute Kidney Injury in Predisposed Patients
Osama Ali Diab, Mostafa Helmy, Yasser Gomaa and Reem El-Shalakany

Circ Cardiovasc Interv. 2017;10:e004348
doi: 10.1161/CIRCINTERVENTIONS.116.004348
Circulation: Cardiovascular Interventions is published by the American Heart Association, 7272 Greenville Avenue, Dallas, TX 75231
Copyright © 2017 American Heart Association, Inc. All rights reserved.
Print ISSN: 1941-7640. Online ISSN: 1941-7632

The online version of this article, along with updated information and services, is located on the World Wide Web at:
http://circinterventions.ahajournals.org/content/10/1/e004348

Permissions: Requests for permissions to reproduce figures, tables, or portions of articles originally published in Circulation: Cardiovascular Interventions can be obtained via RightsLink, a service of the Copyright Clearance Center, not the Editorial Office. Once the online version of the published article for which permission is being requested is located, click Request Permissions in the middle column of the Web page under Services. Further information about this process is available in the Permissions and Rights Question and Answer document.

Reprints: Information about reprints can be found online at:
http://www.lww.com/reprints

Subscriptions: Information about subscribing to Circulation: Cardiovascular Interventions is online at:
http://circinterventions.ahajournals.org//subscriptions/