Automated carbon dioxide digital angiography for lower limb arterial disease evaluation: safety assessment and comparison with standard iodinated contrast media angiography.

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Aims and objectives

Introduction: Carbon dioxide (CO₂) has been validated as contrast agent in a large series of studies. A particular advantage of CO₂ over iodinated contrast medium (ICM) is an absence of both nephrotoxicity and allergic reactions. The main limitation of CO₂ angiography was the difficulty of CO₂ automated injection due to its compressibility. The manual gas injection does not permit an optimal control of the gas output. Development of an automated CO₂ injector has overcome these problems.

Aim: it was to compare the feasibility, safety, and diagnostic accuracy of CO₂ digital subtraction angiography (DSA) in comparison with ICM DSA in the evaluation of lower extremity arterial disease.

Fig. 1: Above the knee imaging comparing ICM and CO₂ angiography. ICM = iodinated contrast media; CO₂ = carbon dioxide

References: Policlinico di Monza - Monza/IT
Methods and materials

MATERIAL AND METHODS

Patients

During an 8-month period, from September 2012 to April 2013, 40 patients affected by critical limb ischemia underwent lower limb angiography with both ICM and CO\textsubscript{2} contrast agents to directly compare the two techniques. Sixteen female and 24 male patients participated; their mean age was 71.7 years (range, 50-82 years). The baseline clinical characteristics of the treated patients are shown in Tables 1 and 2. Medical illnesses included the following: diabetes in 24 patients, chronic renal insufficiency in 31 patients, hypertension in 23 patients, stable coronary artery disease in 9 patients, chronic obstructive pulmonary disease in 5 patients, and cerebrovascular disease in 4 patients.
A relative contraindication to ICM was chronic renal insufficiency (serum creatinine ≥ 1.3 mg/dl). Approval for the study was obtained from the Local Ethics Committee, and informed consent was obtained from each patient at the time of the investigation. The patients who consented to participate in the study had angiography performed with both CO₂ and ICM to directly compare the two techniques. Carbon dioxide DSA was performed before ICM DSA in the same procedure.

**Images for this section:**

**Tab. 1**

<table>
<thead>
<tr>
<th>Table 1. Population characteristics.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Female gender</td>
</tr>
<tr>
<td>Age</td>
</tr>
<tr>
<td>Diabetes</td>
</tr>
<tr>
<td>Hypertension</td>
</tr>
<tr>
<td>CAD</td>
</tr>
<tr>
<td>Hypercholesterolemia</td>
</tr>
<tr>
<td>TIA</td>
</tr>
<tr>
<td>COPD</td>
</tr>
<tr>
<td>Smoker</td>
</tr>
<tr>
<td>Creatinine ≥ 1.3 mg/dl</td>
</tr>
<tr>
<td>Creatinine ≥ 2 mg/dl</td>
</tr>
</tbody>
</table>

CAD = coronary artery disease; TIA = transient ischemic attack; COPD = chronic obstructive pulmonary disease
### Results

The two investigative methods were compared by analysis of the nine territories in the entire group of 40 patients with a total number of 360 evaluated segments. **Table 3** shows an overall diagnostic accuracy of 96.9% for CO\(_2\) DSA, using ICM DSA as the gold standard (sensitivity 99.0%; specificity 96.1%; PPV 91.1%; NPV 99.6%). The diagnostic accuracy was 97.1% in the ATK district (sensitivity 100%; specificity 96.2%; PPV 88.7%; NPV 100%) and 96.7% in the BTK district (sensitivity 97.9%; specificity 95.8%; PPV 94.0%; NPV 98.6%). The diagnostic accuracy values of CO\(_2\) DSA in the nine districts taken individually are shown in **Table 4**. No significant decline in renal function was observed in patients with a normal basal creatinine value (average 0.10 mg/dl), but the average increase in serum creatinine level was 0.24 mg/dL (p < 0.001) in patients who were considered most at risk (serum creatinine level # 2 mg/dL). Tolerable minor symptoms, including foot pain, occurred in 3 patients, and 1 patient experienced nausea. No cardiovascular events were noted while monitoring the patients during and after the CO\(_2\) injections. No life-threatening complications occurred during the use of CO\(_2\) DSA. No allergic reactions were noted following CO\(_2\) injection, although 3 patients experienced reversible cutaneous erythema after ICM injection.
### Tab. 3

**Table 3** CO₂-angiography diagnostic accuracy in the ATK, BTK and overall districts.

<table>
<thead>
<tr>
<th></th>
<th>ATK</th>
<th>BTK</th>
<th>OVERALL</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sensitivity</strong></td>
<td>100 (93.5-100)</td>
<td>97.9 (88.9-99.9)</td>
<td>99.0 (94.7-100)</td>
</tr>
<tr>
<td><strong>Specificity</strong></td>
<td>96.2 (92.4-98.5)</td>
<td>95.8 (88.3-99.1)</td>
<td>96.1 (93.0-98.1)</td>
</tr>
<tr>
<td><strong>PPV</strong></td>
<td>88.7 (78.1-95.3)</td>
<td>94.0 (83.5-98.7)</td>
<td>91.1 (84.2-95.6)</td>
</tr>
<tr>
<td><strong>NPV</strong></td>
<td>100 (97.9-100)</td>
<td>98.6 (92.3-100)</td>
<td>99.6 (97.8-100)</td>
</tr>
<tr>
<td><strong>Accuracy</strong></td>
<td>97.1 (94.1-98.8)</td>
<td>96.7 (91.7-99.1)</td>
<td>96.9 (94.6-98.5)</td>
</tr>
</tbody>
</table>

ATK = above the knee; BTK = below the knee; PPV = positive predictive value; NPV = negative predictive value

### Tab. 4

**Table 4** CO₂ DSA diagnostic accuracy in the nine districts model.

<table>
<thead>
<tr>
<th>CIA</th>
<th>EIA</th>
<th>CFA</th>
<th>PFA</th>
<th>SFA</th>
<th>PA</th>
<th>ATA</th>
<th>PTA</th>
<th>PEA</th>
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</thead>
<tbody>
<tr>
<td><strong>Sensitivity</strong></td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>92.3</td>
<td>100</td>
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<td>(59-100)</td>
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<td>(29-100)</td>
<td>(88-100)</td>
<td>(59-100)</td>
<td>(84-100)</td>
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<tr>
<td><strong>Specificity</strong></td>
<td>100</td>
<td>90.9</td>
<td>97.1</td>
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<td>90.0</td>
<td>97.0</td>
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<tr>
<td></td>
<td>(91-100)</td>
<td>(76-98)</td>
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<td>(86-100)</td>
<td>(55-100)</td>
<td>(84-100)</td>
<td>(81-100)</td>
<td>(82-100)</td>
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<tr>
<td><strong>PPV</strong></td>
<td>100</td>
<td>70.0</td>
<td>83.3</td>
<td>75.0</td>
<td>96.8</td>
<td>87.5</td>
<td>92.3</td>
<td>100</td>
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<tr>
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<td>(35-93)</td>
<td>(36-100)</td>
<td>(19-99)</td>
<td>(83-100)</td>
<td>(47-100)</td>
<td>(64-100)</td>
<td>(84-100)</td>
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<tr>
<td><strong>NPV</strong></td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>96.3</td>
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<td>(82-100)</td>
</tr>
<tr>
<td><strong>Accuracy</strong></td>
<td>100</td>
<td>92.5</td>
<td>97.5</td>
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<td>97.5</td>
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<td>(80-98)</td>
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<td>(87-100)</td>
<td>(87-100)</td>
<td>(87-100)</td>
<td>(83-99)</td>
<td>(91-100)</td>
</tr>
</tbody>
</table>

DSA = digital subtraction angiography; CIA= common iliac artery; EIA= external iliac artery; CFA= common femoral artery; PFA= profunda femoral artery; SFA= superficial femoral artery; PA= popliteal artery; ATA= anterior tibial artery; PTA= posterior tibial artery; PEA= peroneal artery
Conclusion

CONCLUSIONS

CarbonDioxide DSA using the Angiodroid® automated delivery system is a safe alternative technique for the evaluation of patients with PAD of the lower limbs. Adequate opacification of the ATK and BTK arteries can be obtained with proper injection technique. We suggest that CO₂ should be used as the initial contrast agent for the evaluation of PAD in patients with renal failure and iodine contrast allergy. For infrapopliteal segment opacification we recommend selective injection as close to the target artery as possible. To maximally optimize imaging, the proceduralist must take advantage of the special properties of CO₂. This requires some changes in angiographic techniques from contrast preparation to image post-processing.
Personal information

References

REFERENCES


