Comparison of Oxygen Saturation of Blood in Azygos Vein and Superior Vena Cava

By Kewal K. Jain, M.D., Henry R. Wagner, M.D., and Edward C. Lambert, M.D.

SUMMARY
Blood samples from the superior vena cava (SVC) are usually considered an acceptable representation of mixed systemic venous return in identifying and quantifying left-to-right atrial shunts. However, if during sampling from the SVC unrecognized entrance of the catheter into the azygos vein takes place, diagnostic errors may result. Blood samples from the azygos vein were collected from 60 children with congenital heart disease and the oxygen saturations ranged from 20% to 92%. These saturations were compared to those of samples taken from the superior vena cava above the entrance of the azygos vein. No substantial difference (saturation within ±4%) was found in 24 patients, while 28 patients had a significantly higher saturation in the azygos vein (from +5% to +21%) and eight patients had a lower saturation (from −5% to −16%). A significant left-to-right shunt may be overlooked or erroneously thought to be present when sampling of blood takes place unknowingly from the azygos vein. Examples are presented.

Approaching from the groin it was possible to catheterize the azygos vein in two thirds of the cases when a deliberate attempt was made to do so.

Additional Indexing Words:
Cardiac catheterization, Shunts, Ventricular septal defect, Atrial septal defect

Since the initial description of the azygos vein by Galen, many workers have noted its wide anatomic variations. It is accepted that the azygos vein may act as a bypass between the inferior and superior caval system. However, there is lack of information regarding the oxygen saturation of blood returning from the azygos vein into the superior vena cava (SVC). Blood samples obtained from the SVC are usually considered to approximate mixed systemic venous return.¹ The oxygen saturation of the azygos blood may be different from that of the caval blood so that blood samples taken inadvertently from, or at the entrance of, the azygos vein, may mask or be indicative of a left-to-right shunt. This investigation was carried out to determine the variability of oxygen saturation between blood from the azygos vein and mixed venous samples obtained from other sites.

Methods
In 60 children undergoing diagnostic cardiac catheterization for congenital heart disease, blood samples were obtained from the azygos vein and the SVC above the entrance of the azygos vein. Forty patients had shunt lesions (unidirectional or bidirectional, at different levels), 15 had pure obstructive lesions* (pulmonic stenosis, aortic

*Shunts were excluded by selective angiocardiography from right and left heart chambers.
stenosis, or coarctation of the aorta), and five had no heart disease. The age of the patients ranged from 5 months to 16 years. Three quarters of them were between the age of 5 to 8 years; the rest were equally distributed above and below these ages. The children received a standard sedative mixture and were studied in a fasting state and supine position. The catheter introduced from the groin was advanced into the SVC above the junction with the right atrium and by rotating the tip posteriorly the azygos vein could usually be entered. This attempt was successful in approximately two thirds of patients undergoing cardiac catheterization. Often it was possible to advance the catheter farther through the azygos vein to below the diaphragm. Occasionally the azygos vein was unintentionally entered when the catheter was directed into the SVC.

A hand injection of diatrizoate (Hypaque 75%) confirmed the presence of the catheter in the azygos vein. Blood samples were obtained in quick succession from the azygos vein, from the SVC above the entrance of the azygos vein, from the mid right atrium, and from the IVC. The oxygen saturation of these samples was determined by a calibrated American Optical oximeter.

Two patients with absent inferior vena cava and azygos continuation were eliminated from the study.

Results

The oxygen saturation of blood samples taken from the azygos vein for all patients varied between 20% and 92%. For the 50 patients with full peripheral arterial oxygen saturation, oxygen saturations from the azygos vein ranged between 60% and 92% (mean, 78%). Ten patients with peripheral arterial oxygen desaturation due to right-to-left shunts showed an azygos vein saturation between 20% and 88% (mean, 57%).

Table 1 lists the variability of oxygen saturation between the azygos vein and SVC above the junction with the azygos. A variation in saturation greater than 4 percentage points was arbitrarily taken as a substantial difference which might lead to an error in the clinical diagnosis. This occurred in 60% of our patients. In 28 patients (47% of the total) the saturation in the azygos vein was significantly higher than in the SVC, while in eight patients (13% of all patients) the oxygen saturation in azygos vein was significantly lower than in the SVC. No significant difference between the saturation in the azygos vein and the SVC was found in 24 patients (40% of the total patients).

While 40% of the patients with peripheral arterial oxygen desaturation showed oxygen saturation significantly lower in azygos vein than in the SVC, this occurred only in 8% of patients with normal peripheral arterial saturation (no heart disease, obstructive lesions, and left-to-right shunts).

Table 2 shows the data obtained on three cases. In each of them samples obtained from the azygos vein, mistakenly thought to be true SVC samples, could have led to an erroneous interpretation regarding the presence or absence of a left-to-right shunt.

Discussion

The anatomy of the azygos system is highly variable. Seib4 found many different patterns

<table>
<thead>
<tr>
<th>Type of malformation</th>
<th>No. of patients</th>
<th>Within ±4% of &gt;4% above SVC</th>
<th>&gt;4% below SVC</th>
<th>O₂ saturation in azygos vein (patients)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Left-to-right shunt</td>
<td>30</td>
<td>14</td>
<td>13</td>
<td>3</td>
</tr>
<tr>
<td>Bidirectional or right-to-left shunt</td>
<td>10</td>
<td>2</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Obstructive lesion</td>
<td>15</td>
<td>6</td>
<td>8</td>
<td>1</td>
</tr>
<tr>
<td>No heart disease</td>
<td>5</td>
<td>2</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td>60</td>
<td>24</td>
<td>28</td>
<td>8</td>
</tr>
</tbody>
</table>

*A variation greater than 4% was arbitrarily taken as a substantial difference which could lead to error in the clinical diagnosis.
OXYGEN SATURATION OF BLOOD IN AZYGOS VEIN

Table 2
Examples of Possible Misleading Effect of Discrepancy of Oxygen Saturations Between Azygos Vein and Superior Vena Cava

<table>
<thead>
<tr>
<th>Case diagnosis</th>
<th>Azygos vein</th>
<th>SVC</th>
<th>RA</th>
<th>IVC</th>
<th>MPA</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Ostium primum atrial septal defect</td>
<td>81</td>
<td>75</td>
<td>78</td>
<td>82</td>
<td>82</td>
</tr>
<tr>
<td>2 Ventricular septal defect</td>
<td>92</td>
<td>75</td>
<td>72</td>
<td>90</td>
<td>83</td>
</tr>
<tr>
<td>3 Ventricular septal defect with pulmonic stenosis</td>
<td>64</td>
<td>78</td>
<td>78</td>
<td>—</td>
<td>83</td>
</tr>
</tbody>
</table>

Abbreviations: SVC = superior vena cava; RA = right atrium; IVC = inferior vena cava; MPA = main pulmonary artery.

of the azygous venous system in the dissection of 200 human adult cadavers. He also demonstrated frequent connection between the IVC or the left renal vein and the azygous system. Anson and associates\(^5\) confirmed this finding in 450 autopsies.

Bishop and co-workers\(^6\) reported oxygen saturations of 82% to 91% in the renal veins at rest. Renal venous drainage into the azygous system may be responsible for our finding that the oxygen saturation in that system was frequently higher than the best mixed venous oxygen saturation. In the majority of our cases, the increase in oxygen saturation in azygous vein blood was also accompanied by an increase in saturation in the IVC; this observation suggests a common, highly saturated, venous drainage system such as that from the kidneys.

Furthermore, highly oxygenated blood from the bronchial veins may empty into the azygous system, as described by Shaner.\(^7\) Superficial bronchial veins, such as the pleuro-hilar veins, usually drain into the azygous system.\(^8\) Since bronchial veins communicate freely with the pulmonary veins throughout their course, they may carry highly oxygenated blood.

Finally, anomalous pulmonary veins may empty directly into the azygous vein. Healey\(^9\) reported three cases of partial anomalous pulmonary venous drainage into the azygous vein among 86 cases described. Selective angiocardiography appeared to exclude this anomaly in our patients.

The results from table 1 show that the azygous vein frequently carried higher oxygenated blood than did the SVC. The above-mentioned drainage patterns from renal, bronchial, or pulmonary sites are probably responsible for this tendency.

Azygous vein oxygen saturation more than 5 percentage points below the SVC saturation was encountered less frequently. It occurred mostly among patients with decreased peripheral oxygen saturation due to right-to-left shunts. Venous drainage into the azygous system from tissues with high oxygen extraction may be postulated, but the sites are unknown. Hepatic drainage may be a possibility.

In figure 1 the difference in oxygen saturation in the azygous vein and the SVC was related to the level of the cardiac output. In all the patients with a high cardiac output,
oxygen saturations in the azygos veins were above those in the SVC. A lower oxygen saturation in the azygos vein than in the SVC was frequently found in right-to-left shunts and rarely in obstructive lesions.

Table 2 lists the data on three patients with discrepant oxygen saturations between the azygos vein and SVC. Since the catheter occasionally enters the azygos vein fortuitously, which may not be apparent in the anteroposterior x-ray view, a sample of blood obtained from the azygos vein may be erroneously thought to be from the SVC. In the patient with the ostium primum atrial septal defect (table 2), the high oxygen saturation in azygos vein blood, if interpreted as representative of mixed venous blood, masks the presence of a left-to-right shunt. In the second patient, the one with a ventricular septal defect, the high oxygen saturation in the azygos vein may lead to the consideration of partial anomalous pulmonary venous drainage into the SVC or may mask the large left-to-right shunt at ventricular level. In the third patient, the low oxygen saturation in the azygos vein simulates a left-to-right shunt at the atrial level, but one is not present.

Patients 1 and 2 show the similarity in saturation from the azygos vein and the IVC, suggesting common drainage sites.

References

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