Successful Blood Sampling Through Azygos Continuation With Interrupted Inferior Vena Cava

A Case Report and Review of the Literature

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SUMMARY

Interrupted inferior vena cava (IVC) with azygos continuation is a rare congenital anomaly, and is frequently associated with other cardiovascular malformations and situs anomalies, such as left isomerism. These patients usually develop deep vein thrombosis (DVT), and asymptomatic patients above 60 years of age are very rare. Here we report a case of interrupted IVC which we diagnosed in a 72-year-old woman. She was admitted to our hospital suffering from heart failure and supraventricular tachycardia. Echocardiography detected secundum atrial septal defect (ASD). An abnormal paravertebral pleural line on the chest X-rays indicated the existence of venous anomaly. Anatomical images obtained by Multidetector Computed Tomography (MDCT) helped us to successfully perform right heart catheterization procedures through azygos continuation including blood sampling from pulmonary veins. Even in elderly patients, a careful examination of chest X-rays can indicate undiagnosed venous anomalies; thus, it is critically important before planning surgical or interventional procedures. (Int Heart J 2011; 52: 327-330)

Key words: Interrupted inferior vena cava, Left isomerism, Atrial septal defect, Heart failure

Interrupted IVC with azygos continuation is a rare congenital anomaly, resulting from aberrant development of the IVC segment during embryogenesis.¹⁾ This developmental anomaly results in termination of the IVC below the hepatic vein. Systemic venous flow beyond this point is accommodated by dilated azygos and hemiazygos veins, which eventually empty into the superior vena cava (SVC) through a dilated azygos arch.²⁾

This anomaly is usually associated with recurrent DVT of the lower limbs³⁾ or with sick sinus syndrome⁴⁾ and it is typically detected in the early to middle ages of life (range, 14-56 years, mean, 34.5 ± 13.35 years).⁵⁾

The condition can lead to procedural difficulties and complications during abdominal surgery or catheter intervention that can be life-threatening, if not identified before the procedures.^{3,4,6)} Therefore, an awareness of this anomaly before the procedures is very important, especially if it coexists with congenital cardiac malformation.

Here we report the case of a 72-year-old woman with an interrupted IVC with azygos continuation accompanied by mild secundum ASD. An abnormal paravertebral pleural line on the chest X-rays helped us to detect this venous anomaly, and MDCT angiography confirmed the total interruption of

IVC below the hepatic vein with azygos continuation. These anatomical images helped us to successfully achieve right heart catheterization through azygos continuation procedures including blood sampling.

CASE REPORT

A 72-year-old Japanese woman was admitted with complaints of exertional dyspnea. She had received a diagnosis of paroxysmal supraventricular tachycardia at the age of 63 years, but had no diagnosis of cardiac anomaly.

On physical examination, fixed split of second heart sound and systolic ejection murmur were heard over the left side of the sternal border. ECG showed supraventricular tachycardia. Echocardiography documented enlargement of both atria and secundum ASD (approximately 8×9 mm) shunting from left to right (Figure 1), and normal function of both ventricles. The pulmonary artery pressure was presumed to be about 40 mmHg. Laboratory findings were normal except for mild liver dysfunction. Her brain natriuretic peptide level was elevated to 238.7 pg/mL, and her D-dimer level was within the normal range. Plain chest X-rays showed severe cardiomegaly

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Figure 1. Echocardiographic evaluation showed secundum ASD (arrow; between calipers) shunting from left to right (RA indicates right atrium; LA, left atrium).

Figure 2. A postero-anterior chest X-ray revealed severe cardiomegaly with a prominent SVC. Note an "abnormal right paravertebral pleural line" blending inferiorly with the mediastinum (arrows).

(cardiothoracic ratio = 68%) with a very prominent SVC. An abnormal right paravertebral pleural line was noted in the mediastinum (Figure 2), suggesting the existence of a dilated azygos vein, which is usually accompanied by the continuation of interrupted IVC. MDCT angiography confirmed the total interruption of IVC below the hepatic vein with azygos continuation, draining into the SVC, and the hepatic vein draining directly into the right atrium (Figure 3). It also revealed polysplenia and bilaterally bilobed lungs, but DVT was not detected.

To evaluate the severity of heart failure and ASD, we performed a right heart catheterization procedure, which is required to determine the indication of surgical intervention.

Figure 3. (a) MDCT angiography demonstrated total interruption of the IVC below the hepatic vein with azygos continuation (white arrows), and the hepatic vein draining directly into the right atrium (black arrow). (b) 3D-CT reformation image revealed a dilated azygos vein draining into the SVC (arrows).

Figure 4. (a) Radiograph in the lateral view showing the catheter at the pulmonary artery with an unusual loop because of the interrupted IVC. (b) Diagram demonstrating the passage of the catheter lead through the IVC to the azygos continuation, to the arch of the azygos, down through the SVC, through the right atrium and ventricle and to the pulmonary artery (RA indicates right atrium; RV, right ventricle; PA, pulmonary artery).

Initially we tried to use an upper extremity approach for catheterization; however, the veins of both upper extremities were unsuitable for venipuncture. Therefore, we had to use a femoral vein approach to perform the trans-azygos catheter procedures. In the beginning, the catheter stopped at the hepatic part of the IVC. With careful manipulation, we were able to pass the catheter into the azygos continuation, forward through the arch of the azygos vein, down through the SVC, through the right atrium and ventricle and to the pulmonary artery (Figure 4). The maximum pulmonary artery pressure was 35 mmHg (mean 15 mmHg). Subsequent blood sampling demonstrated oxygen step-up at the right atrium, confirming a left to right shunt ($Q_p/Q_s = 1.51$).

With administration of diuretics and an angiotensin II receptor antagonist, her symptoms of heart failure quickly ameliorated. We and the cardiovascular surgery team decided to continue the medical therapy without performing surgical closure of the ASD, and she was discharged on day 12 of hospitalization. She has been asymptomatic without recurrent heart failure for 3 years since discharge.

Figure 5. a, b: Postero-anterior (a) and lateral (b) chest X-rays of a 67-year-old male with paroxysmal atrial tachycardia. Note the “abnormal right paravertebral pleural line” blending inferiorly with the mediastinum (arrows). An abnormal line in the lateral view (arrowheads) suggested the existence of a dilated azygos vein. c: Postero-anterior chest X-ray of a 65-year-old female with sick sinus syndrome. Note the “abnormal right paravertebral pleural line” blending inferiorly with the mediastinum (arrows).

DISCUSSION

Infrahepatic IVC interruption with azygos continuation is a rare congenital anomaly especially when it is not associated with congenital heart disease. This developmental anomaly results in termination of the IVC below the hepatic vein. Systemic venous flow beyond this point is accommodated by the dilated azygos and hemiazygos veins, which eventually empty into the SVC through a dilated azygos arch.⁷⁾

During embryogenesis, the IVC is made up of the hepatic, prerenal, renal, and postrenal segments. After segmental fusion, regression, and midline anastomosis, they constitute the IVC.⁷⁾ Interruption of the IVC most likely results from agenesis of a segment of the IVC,¹⁾ or a fusion defect between the hepatic and prerenal segment of the IVC.⁸⁻¹⁰⁾ The infrahepatic IVC may continue as the azygos vein or the hemiazygos vein to the left SVC,¹¹⁾ intrathoracic veins,¹²⁾ or anomalous intrahepatic veins.¹³⁾ The hepatic segment of the IVC drains directly into the right atrium, as in this case.

Interrupted IVC can cause procedural difficulties during right heart catheterization,⁶⁾ electrophysiological studies (EPS),⁴⁾ cardiopulmonary bypass surgery, femoral vein catheter advancement, IVC filter placement, and temporary pacing through the transfemoral route,³⁾ if not identified before the procedure. Moreover, it can lead to life-threatening complications during abdominal surgery, because ligation of the azygos vein, the only major route of venous drainage from below the diaphragm, results in death.¹⁴⁾

Therefore, an awareness of the existence of IVC anomalies before surgical or interventional procedures is critically important to safely perform the procedure, especially in a patient with congenital cardiac malformation.

Noninvasive imaging modalities such as MDCT and magnetic resonance imaging are the most reliable methods for identification of these anomalies;^{9,15)} however, their routine use for congenital cardiac anomalies has not been established.

In this case, plain chest X-rays showed an abnormal right

paravertebral pleural line, which represented the dilated azygos vein, and MDCT angiography confirmed total interruption of IVC with azygos continuation. As a dilated azygos vein ascends through the right side of the posterior mediastinum and arches forward, it creates the “right paravertebral pleural line” blending inferiorly with the mediastinum.

We encountered 2 other cases of interrupted IVC with azygos continuation. One was a 67-year-old male with paroxysmal atrial tachycardia (Figures 5a, b) and the other was a 65-year-old female with sick sinus syndrome (Figure 5c), in whom the venous anomaly was identified incidentally during catheter ablation and EPS, respectively. In both cases, chest X-rays showed a “right paravertebral pleural line” blending inferiorly with the mediastinum, indicating that this can be a clue to the diagnosis of the anomaly. Previous reports have shown that an enlarged azygos vein may cause “widening of the mediastinum”,¹⁶⁾ or a “mediastinal mass”,¹³⁾ on chest X-rays. We also emphasize that the “right paravertebral pleural line” should be carefully examined to detect this venous anomaly.

IVC interruption occurs in 0.3% of otherwise healthy individuals and in 0.6-2% of patients with other cardiovascular defects.²⁾ However, this could be an underestimate because some patients can be asymptomatic and remain latent for a long time, as in this case, especially when the interrupted IVC is associated with well-developed azygos or hemiazygos continuation.⁵⁾

Intriguingly, these 3 patients (aged 65-74 years) were much older at the time of diagnosis than those previously reported by others (aged 14-56 years, mean 34.5 ± 13.35 years),⁵⁾ suggesting that this anomaly can be more prevalent among elderly people than expected.

In elderly patients, the veins of the upper extremities are sometimes not suitable as a route of catheterization, as in this case, and the lower extremities have to be used. By referring to the CT image, we carefully negotiated the catheter through the IVC into the azygos continuation, and uneventfully achieved right heart catheterization including blood sampling through the transfemoral route. Others have reported patients with in-

interrupted IVCs in whom EPS,⁴⁾ or temporary pacing³⁾ was performed through the transfemoral route. To our knowledge, this is the first case where right heart catheterization including blood sampling was successfully achieved through the transfemoral route in a patient with interrupted IVC.

This IVC anomaly also represents an excellent marker of left isomerism (polysplenia syndrome).¹⁷⁾ Left isomerism is a variant of heterotaxy associated with paired left-sided viscera that can be linked with complex cardiovascular malformations.¹⁸⁾ Typical findings of left isomerism are: (a) viscerocardiac heterotaxy, (b) structural heart disease, and (c) interrupted IVC with azygos continuation.¹⁸⁻²⁰⁾ Most of these manifestations were present in this case (ASD, polysplenia, bilaterally bilobed lungs, and infrahepatic IVC interruption); thus, our patient was considered to be a case of left isomerism.

Genetically, the disruption of asymmetric expression of the TGF- β family member genes, *NODAL*, *LEFTY-1*, and *LEFTY-2*, have been shown to be associated with left-right axis malformations including heart defects.²¹⁻²⁴⁾ In addition, environmental factors such as diabetes mellitus can also contribute to lateralization defects.^{25,26)} Genetic investigation of our patient is now under consideration.

It was reported that IVC interruption and ASD have extremely high prevalence among fetuses with left isomerism (93% and 71%, respectively),²⁷⁾ suggesting that these malformations can coexist with each other, as in the present case. Therefore, when planning right heart catheterization in patients with ASD, careful examination of chest X-rays and subsequent CT angiography should be considered before the procedure.

In conclusion, we have described a case of left isomerism associated with secundum ASD and IVC interruption found by plain chest X-rays. Right heart catheterization was successfully performed through the azygos continuation. The recognition of IVC anomaly is critically important before catheter and surgical interventions. An abnormal right paravertebral pleural line on plain chest X-rays can be a very strong clue to the diagnosis of this venous anomaly.

REFERENCES

1. Minniti S, Visentini S, Procacci C. Congenital anomalies of the venae cavae: embryological origin, imaging features and report of three new variants. *Eur Radiol* 2002; 12: 2040-55. (Review)
2. Timmers GJ, Falke TH, Rauwerda JA, Huijgens PC. Deep vein thrombosis as a presenting symptom of congenital interruption of the inferior vena cava. *Int J Clin Pract* 1999; 53: 75-6.
3. Vijayvergiya R, Bhat MN, Kumar RM, Vivekanand SG, Grover A. Azygos continuation of interrupted inferior vena cava in association with sick sinus syndrome. *Heart* 2005; 91: e26.
4. Lin KH, Kuo CT, Lin CT. Screw-in atrial lead in a sick sinus syndrome patient with anomalous inferior vena cava. *Jpn Heart J* 2001; 42: 639-44.
5. Koc Z, Oguzkurt L. Interruption or congenital stenosis of the inferior vena cava: prevalence, imaging, and clinical findings. *Eur J Radiol* 2007; 62: 257-66.
6. Ramsaran EK, Filiberti AW, Spodick DH. Isolated anomalous inferior vena cava with azygos drainage. *Cardiology* 1995; 86: 257-8.
7. Chuang VP, Mena CE, Hoskins PA. Congenital anomalies of the inferior vena cava. Review of embryogenesis and presentation of a simplified classification. *Br J Radiol* 1974; 47: 206-13.
8. Mathews R, Smith PA, Fishman EK, Marshall FF. Anomalies of the inferior vena cava and renal veins: embryologic and surgical considerations. *Urology* 1999; 53: 873-80. (Review)
9. Bass JE, Redwine MD, Kramer LA, Huynh PT, Harris JH Jr. Spectrum of congenital anomalies of the inferior vena cava: cross-sectional imaging findings. *Radiographics* 2000; 20: 639-52. (Review)
10. Vijayaraghavan SB, Raja V, Chitra TV. Interrupted inferior vena cava and left-sided subrenal inferior vena cava: prenatal diagnosis. *J Ultrasound Med* 2003; 22: 747-52.
11. Roguin N, Lam M, Frenkel A, Front D. Radionuclide angiography of azygos continuation of inferior vena cava in left atrial isomerism (polysplenia syndrome). *Clin Nucl Med* 1987; 12: 708-10.
12. Arakawa A, Nagata Y, Miyagi S, Takahashi M. Interruption of inferior vena cava with anomalous continuations. *J Comput Tomogr* 1987; 11: 341-5.
13. Beedie RJ, Yeo W, Morcos SK. Congenital absence of the intrahepatic segment of the inferior vena cava with azygos continuation presenting as a mediastinal mass. *Postgrad Med J* 1989; 65: 253-5.
14. Effler DB, Greer AE, Sifers EC. Anomaly of the vena cava inferior; report of fatality after ligation. *J Am Med Assoc* 1951; 146: 1321-2.
15. Fishman EK. From the RSNA refresher courses: CT angiography: clinical applications in the abdomen. *Radiographics* 2001; 21: S3-16. (Review)
16. Applegate KE, Goske MJ, Pierce G, Murphy D. Situs revisited: imaging of the heterotaxy syndrome. *Radiographics* 1999; 19: 837-52. (Review)
17. Pittman C, Reddy M, Reddy ER. Radiological evaluation of inferior vena cava obstruction: pictorial essay. *Can Assoc Radiol J* 1999; 50: 376-83.
18. Berg C, Geipel A, Smrcak J, et al. Prenatal diagnosis of cardio-splenic syndromes: a 10-year experience. *Ultrasound Obstet Gynecol* 2003; 22: 451-9.
19. Peoples WM, Moller JH, Edwards JE. Polysplenia: a review of 146 cases. *Pediatr Cardiol* 1983; 4: 129-37.
20. Ho SY, Cook A, Anderson RH, Allan LD, Fagg N. Isomerism of the atrial appendages in the fetus. *Pediatr Pathol* 1991; 11: 589-608.
21. Lowe LA, Supp DM, Sampath K, et al. Conserved left-right asymmetry of nodal expression and alterations in murine situs inversus. *Nature* 1996; 381: 158-61.
22. Meno C, Saijoh Y, Fujii H, et al. Left-right asymmetric expression of the TGF beta-family member *lefty* in mouse embryos. *Nature* 1996; 381: 151-5.
23. Meno C, Ito Y, Saijoh Y, et al. Two closely-related left-right asymmetrically expressed genes, *lefty-1* and *lefty-2*: their distinct expression domains, chromosomal linkage and direct neuralizing activity in *Xenopus* embryos. *Genes Cells* 1997; 2: 513-24.
24. Meno C, Shimono A, Saijoh Y, et al. *lefty-1* is required for left-right determination as a regulator of *lefty-2* and *nodal*. *Cell* 1998; 94: 287-97.
25. Lin AE, Ticho BS, Houde K, Westgate MN, Holmes LB. Heterotaxy: associated conditions and hospital-based prevalence in newborns. *Genet Med* 2000; 2: 157-172.
26. Slavotinek A, Hellen E, Gould S, Coghill SB, Huson SM, Hurst JA. Three infants of diabetic mothers with malformations of left-right asymmetry—further evidence for the aetiological role of diabetes in this malformation spectrum. *Clin Dysmorphol* 1996; 5: 241-7.
27. Berg C, Geipel A, Kamil D, et al. The syndrome of left isomerism: sonographic findings and outcome in prenatally diagnosed cases. *J Ultrasound Med* 2005; 24: 921-31.