Are Anomalies of the Caval Veins More Common in Complex Congenital Heart Disease?

Tim Lendzian[1], Johannes Vogt[1], Thomas Krasemann[1,2]

[1] Department of Pediatric Cardiology, University Children's Hospital Muenster, Germany,
[2] Department of Paediatric Cardiology, Guys and St Thomas Hospitals, London, UK.

Received: November 21, 2006; revision accepted: March 29, 2007

Key Words:
Vena cava superior · Vena cava inferior · Embryology · Congenital heart disease

Herz 2007;32:657–64

DOI 10.1007/s00059-007-2935-x

Abstract

Background and Purpose: Anomalies of the caval veins are considered to be common cardiac malformations. The knowledge of the varieties of the caval venous system is essential for cardiovascular surgery, pacemaker implantation, intensive care medicine or cardiac catheterization. The authors wanted to know, if anomalies of the caval veins are related to the type and complexity of congenital heart disease.

Material and Methods: The records of 1,631 patients who were catheterized between 1991 and 2003 were reviewed.

Results: 92 of these had anomalies of either the superior or inferior caval vein. 23 had simple congenital heart disease, while in 69 this was considered to be complex ($p < 0.001$). Embryologic considerations are discussed.

Conclusion: It could be proven that anomalies of the caval veins are more often related to complex congenital heart disease. Embryologic considerations show at least a coincidence of the development of the caval veins and of congenital heart disease. For clinical work with these patients the knowledge of these anomalies is important.

Sind Anomalien der Hohlvenen häufiger bei komplexen oder einfachen angeborenen Herzfehlern?

Schlüsselwörter:
Vena cava superior · Vena cava inferior · Hohlvene · Embryologie · Angeborene Herzfehler

Zusammenfassung

Hintergrund und Ziel: Anomalien der Hohlvenen werden zu den häufigen angeborenen Herzfehlern gezählt. Die Kenntnis dieser Anomalien ist für den Chirurgen, den Intensivmediziner und für weitere Interventionen wie Schrittmacherimplantationen oder Herzkatheteruntersuchungen wichtig. Die Autoren wollten beweisen, dass Hohlvenenanomalien häufiger bei komplexen als bei „simplen" angeborenen Herzfehlern sind.

Material und Methodik: Zwischen 1991 und 2003 wurden 1 631 Patienten mit angeborenen Herzfehlern einer Herzkatheteruntersuchung unterzogen. Die Protokolle dieser Untersuchungen wurden auf das mögliche Vorliegen von Hohlvenen- und Situsanomalien geprüft. Des Weiteren wurden die angeborenen Herzfehler als „simpel" klassifiziert, wenn es sich um einen Vorhofseptumdefekt, einen Ventrikelseptumdefekt, ein persistierendes Foramen ovale, eine valvuläre Pulmonal- oder Aortenstenose, eine Aortenisthmusstenose oder einen persistierenden Ductus arteriosus handelte. Als komplex wurden atrioventrikuläre Septumdefekte, Herzfehler mit „single ventricle"-Physiologie (hypoplastisches Linksherz, hypoplastisches Rechtsherz, singuläre Ventrikel), Doppelauslassventrikel, die Fallot-Tetralogie, komplette Lungenvenenfehlmündung, „single atrium" und Pulmonalatresien eingestuft. Die Hohlvenenanomalien in den beiden Gruppen wurden nun miteinander verglichen.

Ergebnisse: Insgesamt lagen 92 Hohlvenenanomalien vor; davon waren 23 (25%) mit einfachen und 69 (75%) mit komplexen Vitien assoziiert ($p < 0{,}001$). 66 Patienten hatten Anomalien der oberen Hohlvenen, wovon 20 (30,3%) mit simplen Herzfehlern vergesellschaftet waren ($p < 0{,}001$). Die häufigste Fehlbildung der oberen Hohlvene war eine persistierende linke obere Hohlvene. 26 Fehlbildungen der unteren Hohlvene wurden gefunden; davon waren 23 (88,5%) mit komplexen kardialen Vitien assoziiert ($p < 0{,}001$). Weitere Details sind in Tabellen 1 bis 5 aufgelistet.

Schlussfolgerung: Es konnte bewiesen werden, dass Anomalien der Hohlvenen signifikant häufiger mit komplexen angeborenen Herzfehlern vergesellschaftet sind. Überlegungen zur Embryologie weisen zumindest auf einen zeitlichen Zusammenhang mit der Enstehung möglicher Vitien hin. Die Kenntnis möglicher Anomalien ist für die klinische Arbeit mit diesen Patienten unerlässlich.

Introduction

Congenital anomalies of the caval veins are considered to be common cardiac malformations [12]. Situs anomalies are frequently associated with anomalies of the systemic venous return, but a left superior caval vein (SVC) might be considered normal in situs inversus [22].

Malformations of the SVC include malconnection of a right SVC to the left atrium, absence of the right caval vein with a persistent left upper caval vein (PLSVC), that can be connected to the right atrium, the coronary sinus, the azygos vein or the left atrium [12,17]. A If a right and left SVC are present, this is called bilateral SVCs (Figures 1 to 4) [17,24]. Additionally, one case of complete absence of the SVC has been published [13].

Malformations of the inferior caval vein (IVC) include duplication, interruption or absence with azygos continuity, and connection with the left atrium. Parts or the whole of the vessel might be located on the left side of the body (Figure 5) [17, 23].

Total misconnections of both SVC and IVC to the left atrium have been described [17].

Agenesis of the IVC is rare [26] and occurs as a segmental malformation [19]. An interrupted IVC with azygos continuity is often associated with a malformation of the portal vein [14].

Diagnosis

Most caval abnormalities can be diagnosed by echocardiography including colored Doppler technology [6, 9].

Routine chest X-rays of patients with PLSVC may show a shadow formed like a half moon just under the mid third of the clavicle [3, 17]. Magnetic resonance imaging or computed tomography with contrast dye are adequate methods to diagnose malformations of venous vessels [26].

Cardiac catheterization allows both anatomic and hemodynamic assessment and is therefore still the gold standard.

Caval malformations are often associated with other congenital heart disease [12]. We wanted to know, if malformations of the caval vein system are more frequently associated with simple or with complex congenital heart disease.

Material and Methods

In a retrospective analysis, all heart catheter records of the University Children's Hospital Muenster, Germany, from 1991 to 2003 were reviewed. In 1,631 patients, 2,483 catheterizations were performed. Every patient with congenital heart disease underwent heart catheter

Table 1. Noncomplex congenital heart disease (CHD) found in the study population.
AS: aortic stenosis; ASD: atrial septal defect; CoA: coarctation of the aorta; PDA: persistent arterial duct; PFO: persistent foramen ovale; PST: pulmonary stenosis; VSD: ventricular septal defect.

Tabelle 1. „Simple" angeborene Herzfehler (CHD) in der Studienpopulation.
AS: Aortenstenose; ASD: Vorhofseptumdefekt; CoA: Aortenisthmusstenose; PDA: persistierender Ductus arteriosus; PFO: persistierendes Foramen ovale; PST: Pulmonalstenose; VSD: Ventrikelseptumdefekt.

CHD	Patients (n)[a]
VSD	478
ASD	357
PST	293
CoA	204
PDA	197
AS	135
PFO	39

[a] Different types of CHD appeared in combination, so the total number is not the same as the total number of individuals in the study population

Table 2. Complex congenital heart disease (CHD) found in the study population.
AVSD: atrioventricular septal defect; DOLV: double outlet left ventricle; DORV: double outlet right ventricle; HLH: hypoplastic left heart; HRH: hypoplastic right heart; PA: pulmonary atresia; SA: single atrium; SV: single ventricle; TAPVR: total anomalous pulmonary venous return; TGA: transposition of the great arteries; TOF: tetralogy of Fallot.

Tabelle 2. Komplexe angeborene Herzfehler (CHD) in der Studienpopulation.
AVSD: atrioventrikulärer Septumdefekt; DOLV: linker Doppelauslassventrikel; DORV: rechter Doppelauslassventrikel; HLH: hypoplastisches Linksherz; HRH: hypoplastisches Rechtsherz; PA: Pulmonalatresie; SA: „single atrium"; SV: „single ventricle"; TAPVR: totale Lungenvenenfehlmündung; TGA: Transposition der großen Arterien; TOF: Fallot-Tetralogie.

CHD	Patients (n)[a]
TGA	138
TOF	132
AVSD	121
PA	75
SV	61
HLH	50
DORV	32
TAPVR	31
HRH	21
SA	4
DOLV	2

[a] Different types of CHD appeared in combination, so the total number is not the same as the total number of individuals in the study population

diagnostics prior to surgery to rule out (or prove) caval anomalies. The only exceptions were neonates with coarctation of the aorta (CoA), transposition of the great arteries (TGA) and hypoplastic left heart syndrome (HLH) prior to Norwood I palliation. The latter were catheterized before step II palliation.

The type of congenital heart disease, anomalies of the caval vein system and situs situation were listed for each patient.

The underlying congenital heart disease was considered to be "simple", if the diagnosis was atrial septal defect (ASD), persistent foramen ovale (PFO), ventricular septal defect (VSD), pulmonary stenosis (PST), CoA, persistent arterial duct (PDA) and valvular aortic stenosis (AS).

TGA, atrioventricular septal defect (AVSD), single-ventricle (SV) lesions, pulmonary atresia (PA), anomalous pulmonary venous return (APVR), tetralogy of Fallot (TOF), double outlet right ventricle (DORV), single atrium (SA), HLH, hypoplastic right heart (HRH), double inlet or outlet left ventricle (DILV/DOLV) and other severe rare constellations of congenital heart disease were defined as "complex".

Malformations of the caval vein system were differentiated between PLSVC, missing right IVC, left IVC and missing or incomplete IVC with azygos continuity.

The caval malformations were related to "simple" or "complex" congenital heart disease. To compare these groups, Student's t-test was used with the help of the program Microsoft Excel 11.56 (Microsoft Corp).

Literature was reviewed using the online database "pubmed" and the "Index Medicus".

Results

The study population consisted of 1,631 patients. In this population, 1,593 patients (97.7%) suffered from a cardiovascular malformation (Tables 1 and 2). Absence of cardiovascular malformation could be diagnosed in 38 cases (2.4%). These patients underwent cardiac catheterization either for cardiomyopathy or to securely exclude congenital heart disease.

The total number of patients with a malformation of either SVC or/and IVC was 92. One of these patients had a PLSVC without any further associated congenital heart disease. 23 of them (25%) were associated with simple and 69 with complex congenital heart disease (Tables 3 and 4).

There were 66 patients with a malformation of the SVC system (Table 5). 20 cases (30.3% of the 66 patients) were associated with simple congenital heart disease, 46 patients (69.7%) had an association with complex congenital heart disease (Table 5). The difference was significant ($p < 0.001$; Table 5).

Table 3. Patients with malformation of the caval vein system and associated simple congenital heart disease (CHD).
AS: aortic stenosis; ASD: atrial septal defect; CoA: coarctation of the aorta; IVC: inferior caval vein; PDA: persistent arterial duct; PST: pulmonary stenosis; SVC: superior caval vein; VSD: ventricular septal defect.

Tabelle 3. Patienten mit Fehlbildungen des Hohlvenensystems und assoziierten simplen angeborenen Herzfehlern (CHD).
AS: Aortenstenose; ASD: Vorhofseptumdefekt; CoA: Aortenisthmusstenose; IVC: untere Hohlvene; PDA: persistierender Ductus arteriosus; PST: Pulmonalstenose; SVC: obere Hohlvene; VSD: Ventrikelseptumdefekt.

CHD	Patients (n)	(%)	Malformation SVC (n)	Malformation IVC (n)
No additional CHD	1	1.1	1	–
VSD	8	8.7	7	1
ASD	6	6.5	6	–
PDA	3	3.3	2	1
CoA	3	3.3	3	–
PST	1	1.1	–	1
Subvalvular AS	1	1.1	1	–
Total	23	25	20	3

The anomalies of the SVC could be subdivided into different groups: 55 patients showed a PLSVC and a right SVC. These are 3.4% of all patients, and 83.3% of all patients with an anomaly of the SVCs. In this subgroup we listed the patient with a PLSVC and absent congenital heart disease.

One patient had a situs inversus with bilateral SVCs.

We found five cases (all of them with situs solitus) with a left SVC and absent right SVC (0.3% of all patients, 5.4% of all caval malformations, and 7.6% of all superior caval malformations). All of them had an associated complex congenital heart disease (Table 5).

Four patients with persistent right upper caval vein (PRSVC) and situs inversus could be identified (0.25% of all, 4.3% of all caval abnormalities, and 6.1% of all SVC malformations). A left SVC was present in all of them (this can be considered to be the normal situation in situs inversus). All had associated complex congenital heart diseases (Table 5).

We identified two patients with isomeric situs and a malformation of the caval vein system, one of them with PRSVC and the other one with a left SVC.

One patient revealed complete absence of the SVCs and a bilateral hemiazygos continuity. This constellation was associated with a situs solitus, a TOF and hypoplastic pulmonary arteries on both sides. This case was published before [13].

Another patient showed bilateral SVCs. The right SVC led into the left SVC which itself was con-

Table 4. Patients with malformation of the caval vein system and associated complex congenital heart disease (CHD).
ASD: atrial septal defect; AVSD: atrioventricular septal defect; DILV: double inlet left ventricle; DORV: double outlet right ventricle; HLH: hypoplastic left heart; HLV: hypoplastic left ventricle; HRH: hypoplastic right heart; IVC: inferior caval vein; MS: mitral stenosis; PA: pulmonary atresia; PST: pulmonary stenosis; SA: single atrium; SV: single ventricle; SVC: superior caval vein; TAPVR: total anomalous pulmonary venous return; TGA: transposition of the great arteries; TOF: tetralogy of Fallot; VSD: ventricular septal defect.

Tabelle 4. Patienten mit Fehlbildungen des Hohlvenensystems und assoziierten komplexen angeborenen Herzfehlern (CHD).
ASD: Vorhofseptumdefekt; AVSD: atrioventrikulärer Septumdefekt; DILV: linker Doppeleinlassventrikel; DORV: rechter Doppelauslassventrikel; HLH: hypoplastisches Linksherz; HLV: hypoplastischer linker Ventrikel; HRH: hypoplastisches Rechtsherz; IVC: untere Hohlvene; MS: Mitralstenose; PA: Pulmonalatresie; PST: Pulmonalstenose; SA: „single atrium"; SV: „single ventricle"; SVC: obere Hohlvene; TAPVR: totale Lungenvenenfehlmündung; TGA: Transposition der großen Arterien; TOF: Fallot-Tetralogie; VSD: Ventrikelseptumdefekt.

CHD	Patients (n)	(%)	Malformation SVC (n)	Malformation IVC (n)
SV	15	16.3	8	7
AVSD	8	8.7	7	1
TOF	8	8.7	5	3
ASD + VSD	5	5.4	3	2
DORV	4	4.3	3	1
PA	4	4.3	4	–
TAPVR	2	2.2	2	–
TGA	2	2.2	1	1
Combined mitral malformation	1	1.1	1	–
Cor triatriatum	1	1.1	1	–
Dextrocardia + right aortic arch + ASD + PST + MS	1	1.1	1	–
Dextrocardia + TAPVR	1	1.1	1	–
Dextrocardia + TGA	1	1.1	1	–
DORV + AVSD	1	1.1	1	–
HLH	1	1.1	1	–
HRH	2	2.2	1	1
DILV	1	1.1	–	1
HLV + AVSD	1	1.1	–	1
Supravalvular PST + hypoplastic aortic arch	1	1.1	–	1
Supravalvular PST + dysplastic aortic valve	1	1.1	1	–
SA	1	1.1	–	1
SV + DORV + SA	1	1.1	1	–
SV + PA	1	1.1	1	–
SV + PA + TGA	1	1.1	1	–
SV + TGA	1	1.1	–	1
Truncus arteriosus communis	1	1.1	–	1
TAPVR + ASD	1	1.1	–	1
TAPVR + AVSD	1	1.1	1	–
Total	69	75	46	23

Total (Tables 3 and 4): n = 92, SVC: n = 66, IVC: n = 26

nected to the right atrium. An azygos vein was absent. Associated malformations were an imbalanced AVSD with a hypoplastic left ventricle and a total anomalous pulmonary venous return (TAPVR) into the right atrium.

The third case, a patient with dextrocardia in situs solitus, had a left SVC, an absent right SVC and a right azygos vein which collected the venous blood from the right upper half of the body and finally led into the right IVC. Associated were right aortic arch, an ASD, a valvular and infundibular PST, and a mitral stenosis.

26 of the patients (1.6% of all reviewed patients, and 28.3% of all caval malformations) had a malformation of the IVC system (Tables 3 and 4).

In this group, 20 patients showed an azygos continuity (19.6% of all patients with caval anomalies, and 76.9% of all patients with a malformation of the IVCs).

Three patients (11.5% of all patients of this subgroup) had a malformation of the IVC associated with a simple type of congenital heart disease, 23 patients (88.5%) had an association with complex congenital heart disease (Table 5). Even in this group, malformation of the IVC was significantly more often associated with complex congenital heart disease ($p < 0.001$; Table 5).

17 patients with absent IVC were identified (1.0% of all reviewed patients, 18.5% of all patients with anomalies of the caval vein system, and 65.4% of all IVC malformations; Table 5). 14 of these patients had azygos continuity, one showed hemiazygos continuity.

15 patients had a situs solitus, one patient showed a situs inversus, and one patient had right isomerism. Three cases (17.6% of all patients of this subgroup) with absent IVC were associated with simple congenital heart disease; 14 of them (82.4%) with complex congenital heart disease (Table 5).

Four patients showed an interrupted IVC (Table 5). These are 0.25% of all patients, 4.3% of the patients with caval vein anomalies, and 15.4% of the patients with anomalies of the IVC. In three cases, the interruption was located in the hepatic part of the IVC. One of them impressed with a collateral circulation via the azygos vein; another case had a collateral circulation via the hemiazygos vein.

One patient with interrupted IVC had an association with noncomplex congenital heart disease. The remaining three were associated with complex types of congenital heart disease (Table 5). Three of the patients of this subgroup had situs solitus and one had a situs inversus.

Four patients showed a left-sided IVC (0.25% of all reviewed patients, 4.3% of all patients with a caval malformation, and 15.4% of all patients with an anomaly of the IVC system; Table 5), three of them

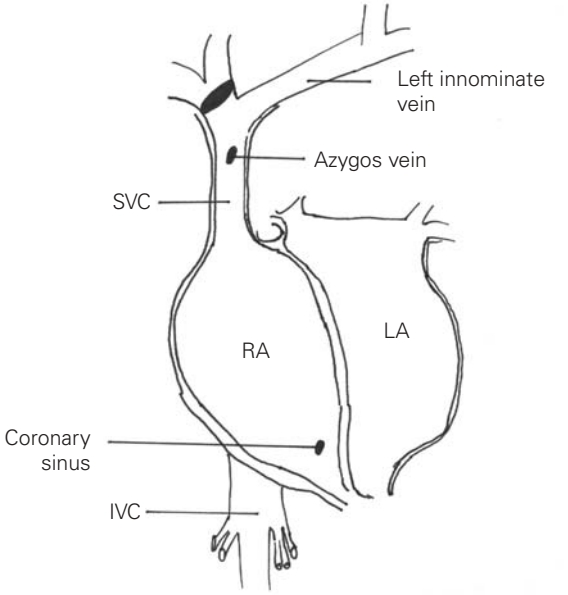

Figure 1. Normal systemic venous return (modified from [20]). IVC: inferior caval vein; LA: left atrium; RA: right atrium; SVC: superior caval vein.

Abbildung 1. Normaler systemvenöser Rückfluss (in Anlehnung an [20]). IVC: untere Hohlvene; LA: linker Vorhof; RA: rechter Vorhof; SVC: obere Hohlvene.

Table 5. Patients with caval malformation and associated congenital heart disease (CHD) subdivided into different types of caval malformation.
IVC: inferior caval vein; LIVC: left inferior caval vein; LSVC: left superior caval vein; PLSVC: persistent left superior caval vein; PRSVC: persistent right superior caval vein; RSVC: right superior caval vein; SVC: superior caval vein.

Tabelle 5. Patienten mit Fehlbildungen der Hohlvenen und angeborenen Herzfehlern (CHD), unterteilt in verschiedene Arten von Hohlvenenanomalien.
IVC: untere Hohlvene; LIVC: linke untere Hohlvene; LSVC: linke obere Hohlvene; PLSVC: persistierende linke obere Hohlvene; PRSVC: persistierende rechte obere Hohlvene; RSVC: rechte obere Hohlvene; SVC: obere Hohlvene.

Malformation	Patients (n)	(% of total n = 92)	CHD simple	CHD complex	p-value
SVC	66	71.7	20	46	< 0.001
IVC	26	28.3	3	23	< 0.001
Total	92	100	23	66	
PLSVC + RSVC	55	59.8	20	35	0.045
LSVC – RSVC	5	5.4	–	5	0.004
PRSVC/situs inversus	4	4.3	–	4	0.014
Absent SVC	1	1.1	–	1	
No CHD (n = 1)	1	1.1	–	–	
Absent IVC	17	18.5	3	14	< 0.001
Interrupted IVC	4	4.3	1	3	0.014
Left IVC	4	4.3	–	4	0.014
Disconnected IVC/left atrium	1	1.1	–	1	
Total	92	99.9	24 + 1[a]	67	

[a] one patient without additional CHD

with a completely left-sided vein and one with a partially left-sided vein.

Two of the patients with left-sided IVC had situs inversus, thus, this had to be considered normal. The third patient showed situs solitus. The fourth case had a vein starting in the left body half and turning over to the right side just below the diaphragm to continue in the right half of the chest with normal connection to the right atrium. All four patients of this subgroup had an SV lesion and were subsequently considered to have complex congenital heart disease (Table 5).

One patient (0.06% of all patients, 1.1% of all patients with caval anomalies, and 3.8% of all patients with anomalies of the IVCs) showed a right IVC with connection to the left atrium. This patient had situs solitus and complex congenital heart disease consisting of TAPVR (subcardial type) and an ASD.

Discussion

Even if it seems obvious, it has never been proven that anomalies of the caval veins are more common in complex than in simple types of congenital heart disease (see Table 5). With our data we could show that this thesis is true, even if a few patients (neonates with TGA or CoA) were not included. On the other hand, even all patients including simple lesions like ASD or VSD underwent cardiac catheterization for proper surgical planning.

The clinical impact is obvious: patients with complex congenital heart disease are a group of patients with a high frequency of hospitalization and medical intervention. Knowledge of their anomalies of the SVC and IVC system is important from diagnosis to intensive care and surgery, because during hospitalization central venous lines are often inserted via the internal jugular vein and the subclavian vein to the SVC and right heart, or through the femoral vein and the IVCs. Cardiopulmonary bypass has to be established for surgical treatment of many of these complex lesions; the knowledge of caval anomalies is important for this as well.

The different constellations of malformation are widespread. Perloff [17] described the following variants:

The otherwise normal right SVC can be connected with the left atrium, or might be absent, usually in the presence of a left SVC (PLSVC). A PLSVC might be connected to the coronary sinus, the azygos vein and, worst case, to the left atrium [12]. In 82% of all cases with a PLSVC, a right SVC is present as well [24].

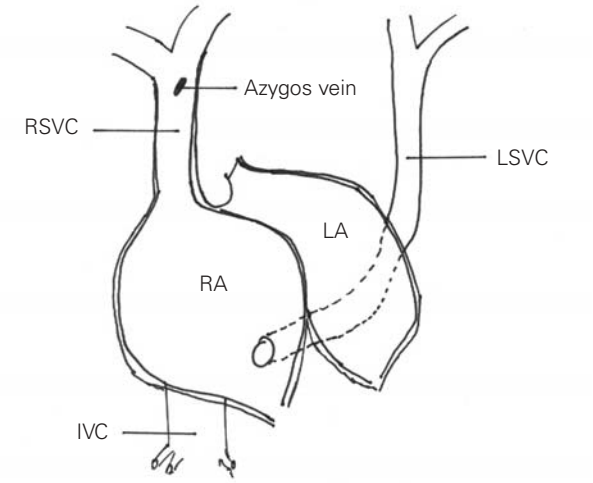

Figure 2. Persistent left superior caval vein (LSVC) draining into the right atrium (RA) via the coronary sinus (modified from [20]). IVC: inferior caval vein; LA: left atrium; RSVC: right superior caval vein.

Abbildung 2. Persistierende linke obere Hohlvene (LSVC) mit Anschluss an den rechten Vorhof (RA) via Koronarsinus (in Anlehnung an [20]). IVC: untere Hohlvene; LA: linker Vorhof; RSVC: rechte obere Hohlvene.

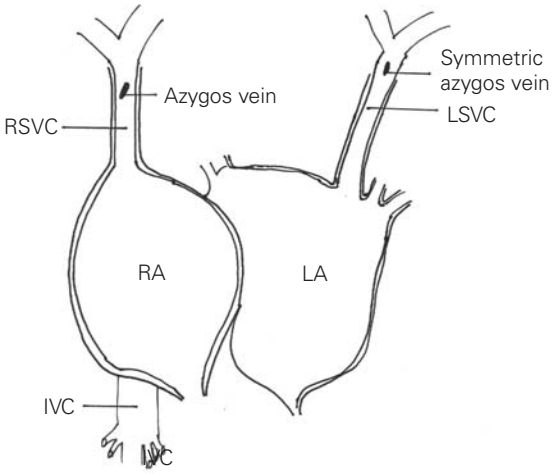

Figure 3. Persistent left superior caval vein (LSVC) with connection to the left atrium (LA; modified from [20]). IVC: inferior caval vein; RA: right atrium; RSVC: right superior caval vein.

Abbildung 3. Persistierende linke obere Hohlvene (LSVC) mit Anschluss an den linken Vorhof (LA; in Anlehnung an [20]). IVC: untere Hohlvene; RA: rechter Vorhof; RSVC: rechte obere Hohlvene.

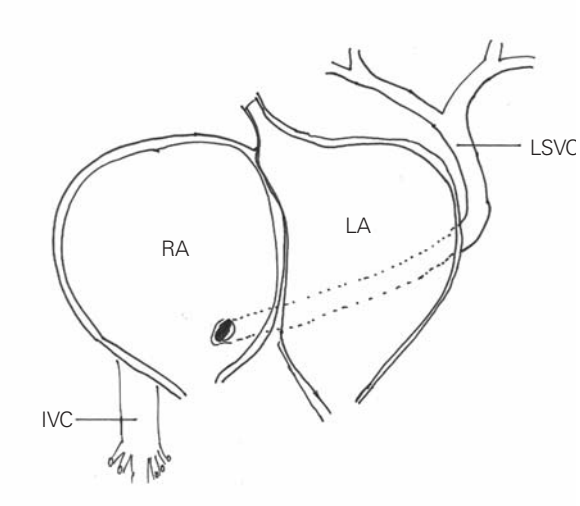

Figure 4. Absent right superior caval vein, left superior caval vein draining into the right atrium (RA; modified from [20]). IVC: inferior caval vein; LA: left atrium.

Abbildung 4. Fehlende rechte obere Hohlvene, Verbindung der linken oberen Hohlvene (LSVC) zum rechten Vorhof (RA; in Anlehnung an [20]). IVC: untere Hohlvene; LA: linker Vorhof.

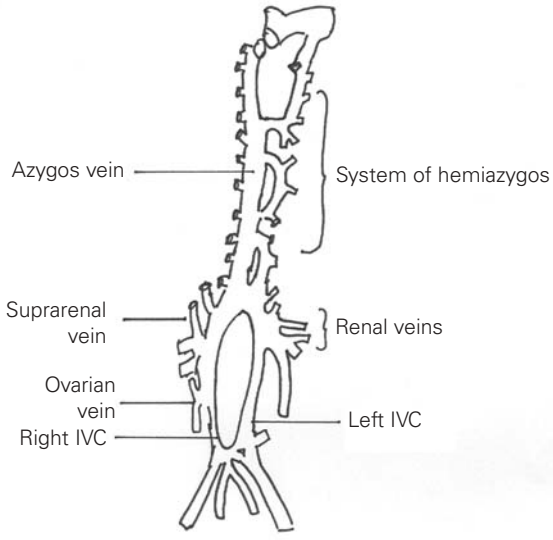

Figure 5. Anomaly of the inferior caval vein (IVC). Azygos and hemiazygos veins replacing the hepatic part of the IVC. Below the renal veins the IVC is doubled (modified from [11]).

Abbildung 5. Anomalie der unteren Hohlvene (IVC). Venae azygos und hemiazygos ersetzen den intrahepatischen Verlauf der IVC. Der infrahepatische Anteil der IVC ist gedoppelt (in Anlehnung an [11]).

If a right and left SVC are present, this is called bilateral SVCs [17, 24]. Additionally, one case of complete absence of the SVC has been published [13].

In 82% of all cases with a PLSVC, a right SVC is present as well [12].

In most cases, a PLSVC is running along the ligamentum Marshalli [12].

Malformations of the IVC include interruption or absence with azygos continuity and connection with the left atrium. Parts or the whole of the vessel might be located on the left side of the body [17].

Total misconnections of both SVC and IVC to the left atrium have been described [17].

A doubled IVC is one of the frequent abnormalities of the IVC (1–3% of the normal population) [23]. Usually, both vessels are connected to the right atrium. An isolated left IVC is less frequent with a prevalence of 0.2% in the normal population [23].

Agenesis of the IVC is rare (0.6% of all human beings according to [26]). In most cases, this is a segmental malformation which is located in the suprarenal segment in 90% and only in 6% in the renal segment [19]. An interrupted IVC with azygos continuity is often associated with a malformation of the portal vein [14].

The hemodynamically worst case of caval malformations is the total malconnection of the systemic veins, which means both the IVC and the SVC are connected to the left atrium.

Associated congenital heart disease in the presence of a PLSVC has been described, one study found an ASD in 40% of the affected individuals [1]. Other associated congenital heart disease were VSD, CoA, TOF, TGA, and PST [1, 15]. Fraser et al. examined 30 patients with PLSVC and found nine patients with ASD, seven patients with TOF, and six patients with anomalous pulmonary venous connection [5]. High coincidence of an ASD and anomalous pulmonary venous connection was also reported by Gensini et al. [7].

Our examination confirms a coincidence of anomalies of the SVC system and ASD and TOF as well (see Tables 3 and 4).

We could not find articles concerning the association of congenital heart disease and malformation of the IVC system.

Interestingly, no literature was available focusing on different types of congenital heart disease and the coincidence of caval anomalies.

Embryologic Considerations

The SVC is formed by a combination of the proximal part of the right anterior cardinal vein and the right common cardinal vein [22].

Above the renal anastomosis the IVC develops from the right subcardinal vein, the hepatic segment is formed by the right vitelline vein, the renal segment by the right subcardinal vein, and the sacrocardinal segment by the right sacrocardinal vein [22].

Development of the caval veins happens during the 5th to the 8th week of pregnancy [22]. This is a critical time for the developing heart, as the cardiac looping finishes during this period and the septation of the heart takes place [22]. The venous flow into the developing heart might contribute to the structural development after it is connected; failure of connection or malconnection might contribute to maldevelopment of cardiac structures, and the other way round. The close association of the developing structures on the timeline might also explain that any disturbance of the development of the cardiac structures might interfere with the venous system as well.

Seven of our patients with malformation of the SVCs had an associated VSD (see Table 3). VSD is the most common congenital cardiac malformation with an incidence of 0.95 : 1,000 live births [10, 18]. The reason for VSD is a developmental failure of the normal ventricular septum which is performed after cardiac looping at days 23–25 after gestation, this is the 4th week of pregnancy [8]. The important period for development of the SVC is set in the 5th week [22]. A chronological coherence is not obvious.

Association of ASD and malformation of the SVCs could be identified in six cases (see Table 3). Septation of the heart takes place between the 3rd and the 6th week [21]. ASDs occur when the wall between the pulmonary vein and vena cava is absorbed [25].

Interestingly, the time of septation of the heart and the development of the caval veins are closely related, but caval anomalies did not occur more frequently with septal defects.

We found 15 cases with caval abnormalities and associated SV, eight of them with malformation of the SVCs and seven with malformation of the IVCs. A failure of the cardiac septation and rotation, leading to SV lesions, between the 3rd and the 6th week might cause difficulties in the remodeling of the caval veins in week 5 and 6.

An AVSD was found in eight patients with caval malformations. In seven cases, this was associated with malformation of the SVCs. AVSD is caused by failure of the endocardial cushions which develop between the 4th and 5th week of pregnancy [4, 21]. A coherence of development of the SVC might be suspected. AVSD was associated with abnormalities of the IVC in one case. Remodeling of the IVC is set a little later than development of the endocardial cushions [22].

Eight patients with caval anomalies showed a TOF. In TOF, failure of the trabecular septum and infundibular septum to unite leads to malalignment [2, 16].

Finally, a coherence of time of embryologic development can be supposed in development of caval abnormalities and associated congenital heart disease. Animal experiments could help to answer these questions.

Conclusion

Anomalies of the caval vein are frequently observed in patients with congenital heart disease. We could prove that caval malformations have a higher prevalence in patients with complex congenital heart disease compared to simple malformations. This might be caused either by complex interference with the cardiac development, or due to the same factors involving both the development of the cardiac structures and the systemic veins.

Conflict of interest: None. The authors declare that they have no financial or personal relations to other parties whose interests could have affected the content of this article in any way, either positively or negatively.

References

1. Bjerregaard P, Laursen HB. Persistent left superior vena cava – incidence, associated congenital heart defects and frontal plane P-wave axis in a pediatric population with congenital heart disease. Acta Paediatr Scand 1980;69:105–8.
2. Clark EB, Van Mierop LHS. Development of the cardiovascular system. In: Adams F, Emmanouilides GC, Riemenschneider TA, eds. Heart disease in infants, children and adolescents. Baltimore: Williams & Wilkins, 1989:9–10.
3. Elliott LP, Jue KL, Amplatz K. A roentgen classification of cardiac malpositions. Invest Radiol 1966;1:17–28.
4. Feldt RH, Porter C, Edwards WD, et al. Defects of the atrial septum and the atrioventricular canal. In: Adams F, Emmanouilides GC, Riemenschneider TA, eds. Heart disease in infants, children and adolescents. Baltimore: Williams & Wilkins, 1989:170–89.
5. Fraser RS, Dvorkin J, Rossall RE, et al. Left superior vena cava. A review of associated congenital heart lesions, catheterisation data and roentgenologic findings. Am J Cardiol 1961; 31:711–6.
6. Geley TE, Unsinn KM, Auckenthaler TM, et al. Azygos continuation of the inferior vena cava: sonographic demonstration of the renal artery ventral to the azygos vein as a clue to diagnosis. AJR Am J Roentgenol 1999;172:1659–62.
7. Gensini G, Caldini P, Blount SG. Persistent left superior vena cava. Am J Cardiol 1959;4:677–85.
8. Gumbiner CH, Takao A. Ventricular septum defect. In: Garson A, Brickner JT, McNamara DG, eds. The science and practice of pediatric cardiology. Philadelphia: Lea & Febiger, 1990:1002–19.
9. Hammerl H. Echokardiographie aktuell: Vena cava superior persistens. J Kardiol 2003;10:392.
10. Hoffman JIE, Rudolph AM. The natural history of ventricular septal defects in infancy. Am J Cardiol 1965;16:634–53.
11. Huseby RA, Boyden EA. Absence of the hepatic portion of the inferior vena cava with bilateral retention of the supracardinal system. Anat Rec 1941;81:537–44.
12. Kaemmerer H, Prokop M, Schirg E, et al. Unilaterale linke Vena cava superior bei fehlender rechter Vena cava superior – moderne bildgebende Diagnostik und klinische Relevanz. Z Kardiol 1994;83:386–91.
13. Krasemann T, Kehl G, Vogt J, et al. Unusual systemic venous return with complete absence of the superior caval veins. Pediatr Cardiol 2003;24:397–9.
14. Le Borgne J, Paineau J, Hamy A. Interruption of the inferior vena cava with azygos termination associated with congenital absence of the portal vein. Surg Radiol Anat 2000; 22:197–202.
15. Momma K, Linde LM. Abnormal rhythm associated with persistent left superior vena cava. Pediatr Res 1969;3:210–6.
16. Neches WH, Park SC, Ettedgui JA. Tetralogy of Fallot and tetralogy of Fallot with pulmonary atresia. In: Garson A, Brickner JT, McNamara DG, eds. The science and practice of pediatric cardiology. Philadelphia: Lea & Febiger, 1990:1073–8.
17. Perloff JK. The clinical recognition of congenital heart disease, 5th edn. Philadelphia: Elsevier Science, 1970:552–60.
18. Pradat P, Francannet C, Harris JA, et al. The epidemiology of cardiovascular defects, part I: A study based on data from three large registries of congenital malformations. Pediatr Cardiol 2003;24:195–221.
19. Shah N, Chanley C, Prince M. Deep venous thrombosis complicating a congenital absence of the inferior vena cava. Surgery 1996;120:891–6.
20. Sherman FE. An atlas of congenital heart disease. Philadelphia: Lea & Febiger, 1963.
21. Sissman NJ. Developmental landmarks and cardiac morphogenesis: comparative chronology. Am J Cardiol 1970;140:41–4.
22. Skandalakis JE, Gray SW, Panagiotis S. The superior and inferior venae cavae. In: Skandalakis JE, Gray SW, eds. Embryology for surgeons. Baltimore: Williams & Wilkins, 1972:1033–51.
23. Ueda J, Hara Y, Kobayashi S. Anomaly of the inferior vena cava observed by CT. Comput Radiol 1983;7:145–54.
24. Van Praagh S, Geva T, Lock JE, et al. Biatrial or left atrial drainage of the right superior vena cava: anatomic, morphogenetic, and surgical considerations – report of three new cases and literature review. Pediatr Cardiol 2003;24:350–63.
25. Vick GW, Titus J. Defects of the atrial septum including the atrioventricular canal. In: Garson A, Brickner JT, McNamara DG, eds. The science and practice of pediatric cardiology. Philadelphia: Lea & Febiger, 1990:1023–54.
26. Ziegler T, Winkler C. Agenesie der Vena cava inferior bei einem 20jährigen Mann. Schweiz Med Forum 2003;38:909–12.

Address for Correspondence
Thomas Krasemann, MD
Department of Paediatric Cardiology
Evelina Children's Hospital
St Thomas Hospital
Lambeth Palace Road
London SE1 7EC
UK
Phone (+44/207) 188-4562,
Fax -4556
e-mail: Thomas.Krasemann@gstt.nhs.uk