Review Article

Brachiocephalic vein aneurysm: a systematic review of the literature

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Abstract: Brachiocephalic vein aneurysms are rare lesions with only 36 cases reported in the literature. They usually present incidentally as mediastinal widening on chest X-ray, with thromboembolism or mass effect on adjacent structures, or rupture. Imaging is usually sufficient to identify and characterize the aneurysm, however, certain diagnostic pitfalls can lead to misinterpretation and misdiagnosis. Exploratory surgery is sometimes needed to confirm diagnosis. Brachiocephalic vein aneurysms have been treated both conservatively with watchful waiting, antithrombotic therapy or anticoagulation as well as surgically depending on patient presentation and aneurysm characteristics. Endovascular treatment is also becoming a therapeutic option. Prognosis following surgical treatment is excellent with no reported cases of recurrence. The present systematic review aims to describe the etiology, clinical presentation, diagnosis, management and outcomes of brachiocephalic vein aneurysms.

Keywords: Brachiocephalic vein aneurysms; innominate vein aneurysms; venous aneurysms

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Introduction

Brachiocephalic vein (or innominate vein) aneurysms are extremely rare. To date, there have only been 36 cases reported in the literature. Brachiocephalic vein aneurysms are more common on the left than on the right side and are often saccular rather than fusiform (1-11). The majority of brachiocephalic vein aneurysms are asymptomatic and discovered incidentally on imaging, though some may present with mass effect on adjacent structures or rupture (2,10-17). As such, the basis of therapy is to prevent aneurysmal progression, thromboembolism or mass effect on adjacent structures, or rupture. While multiple treatment options are available, established guidelines regarding therapy for brachiocephalic vein aneurysms are lacking. The present systematic review aims to describe the etiology, clinical presentation, diagnosis, current management options and outcomes of brachiocephalic vein aneurysms.

Etiology

With the exception of trauma and iatrogenic causes, the true etiology of brachiocephalic vein aneurysms is not well understood. A number of conditions are thought to be associated with brachiocephalic vein aneurysms, including, but not limited to congenital malformation (28%, 10/36 cases) (1,2,4,5,9,12-14,18), hemangioma (8%, 3/36 cases) (5,19,20), hygroma (3%, 1/36 cases) (21), neurofibromatosis

type 1 (NF1) (3%, 1/36 cases) (22), a history of vascular intervention (3%, 1/36 cases), tumor retraction (3%, 1/36 cases) (19), and degeneration of the vessel wall (3%, 1/36 cases) (23).

Congenital defects in vessel structure may cause brachiocephalic vein aneurysm, as described in 28% of patients (10/36 cases) (1,2,4,5,9,12-14,18). These have been reported in association with the histological absence of smooth muscle cells in the aneurysm wall or absence of the adventitia's longitudinal muscle layer, supporting congenital weakness of the vessel wall as a potential underlying cause (4,24).

An association between brachiocephalic vein aneurysms and hemangiomas has also been described in approximately 8% of patients (3/36 reported cases) (5,19,20). Nitta *et al.* reported a case of congenital left and right brachiocephalic vein aneurysms in the setting of angiomatosis, a diffuse form of hemangioma (5,25,26). Akiba (19) and Nakada *et al.* (20) have also reported cases of thymus cavernous hemangioma in association with left brachiocephalic vein aneurysm. Pathological examination showed a transitional portion between the left brachiocephalic vein and cavernous hemangioma, and the tumor appeared to retract the lower portion of the left brachiocephalic vein (19).

Brachiocephalic vein aneurysms have also been reported in association with mediastinal cystic hygromas (3%, 1/36 cases) (21). Among 15 cases of mediastinal cystic hygroma, eight patients were found to have venous aneurysms in the neck and thorax (27). The association between hygroma and venous aneurysms has been attributed to the close embryologic relationship between the lymphatic and venous systems (28).

Finally, there has been one report (3%) of brachiocephalic vein aneurysm as a manifestation of NF1 (22). Pathological examination of the resected aneurysm demonstrated diffuse neurofibroma with an infiltrative pattern. While cardiac and peripheral vascular problems are known clinical complications of NF1 (29), venous aspects of the disorder are poorly understood. Only three other cases of venous aneurysms have been reported in the setting of NF1, all of which involved the internal jugular vein (29-31). Although venous aneurysms are extremely rare manifestations of NF1, they remain a possible finding.

Presentation

The majority of patients with brachiocephalic vein aneurysms are asymptomatic (36%, 13/36 cases) (*Table 1*) (2,10-17).

When symptomatic, brachiocephalic vein aneurysms present with swelling over the supraclavicular and shoulder area (8%, 3/36 cases) (1,18,32), pain (19%, 7/36 cases) (20,22,23,32-35), and cough (19%, 7/36 cases) (1,6,8,19,35-37). Additionally, large or thrombosed aneurysms can have a mass effect on adjacent mediastinal structures, causing other symptoms such as hoarseness (8%, 3/36 cases), dyspnea (11%, 4/36 cases), and respiratory arrest (3%, 1/36 cases).

Diagnosis

Brachiocephalic vein aneurysms are often incidental findings (56%, 20/36 cases). Widening of the mediastinum (28%, 10/36 cases) or presence of a mediastinal mass (47%, 17/36 cases) are the most common findings on chest radiographs. When incidental thoracic masses are suspected, they are often further characterized by computed tomography (CT) (conventional, contrast-enhanced CT or 3D CT) or venography [conventional, CT venography, or magnetic resonance (MR) venography]. Other imaging modalities for the diagnosis of brachiocephalic vein aneurysms include echocardiography, MR imaging (MRI) or duplex ultrasound. In some cases, more invasive approaches such as exploratory thoracoscopy are necessary to confirm diagnosis (13).

On results from cross-sectional imaging methods such as CT, contrast pooling, homogeneous enhancement similar to adjacent venous structures, and continuity with the thoracic veins are often indicative of venous aneurysms (43). Although contrast-enhanced CT is often sufficient to arrive at a diagnosis of brachiocephalic vein aneurysm, common imaging pitfalls are misdiagnosis of the aneurysm as either (I) a solid mediastinal tumour (1,34) or (II) a thymoma (9). As such, should there be any suspicion for misdiagnosis; further workup should be supplemented with the use of multi-modality imaging techniques such as venography, MRI, or transthoracic Doppler study for operative planning.

Differential diagnosis

There is a wide spectrum of potential diagnoses for a mediastinal mass including thymoma, lymphoma, teratoma, neurofibroma, ectopic thyroid gland, lung neoplasm, and arterial aneurysm, among others (44). Despite its rarity, brachiocephalic vein aneurysm should be considered as a differential diagnosis upon discovery of a mediastinal mass, especially in the context of previously reported associations, including congenital malformations (1,2,4,5,9,12-14,18), hemangioma (5,19,20), hygroma (21), neurofibromatosis type 1 (NF1) (22), a history of vascular intervention and

Table 1 Presentation, methods of diagnosis, aneurysm size and location of previously described cases of brachiocephalic vein aneurysms

#	Ref.	Year	Age (yrs)	Sex	Clinical presentation	Venous aneurysms				Diagnostic findings
						BCV	Type	Size (mm)	Others	CXR
1	Harris (1)	1928	5 mo	F	Swelling on R side of neck, spasmodic cough, hoarse cry, cyanosis	L	S	–	R internal jugular	Mediastinal shadow in thymus region
2	Yokomise *et al.* (2)	1990	13	M	Asymptomatic	L	S	50×40	SVC	Mediastinal shadow, shift of cardiac shadow to the L
3	Pasic *et al.* (4)	1995	18	F	Asymptomatic	L, R	S	70×60×50	SVC	Large, R paratracheal mass, partially calcified along superior aspect
4	Nitta *et al.* (5,25,26)	2005, 2006, 2008	1 d	M	Respiratory arrest	L, R	S (L), F (R)	–	None	Mediastinal widening, R pneumothorax
5	Hosein *et al.* (6)	2007	13	F	Nonproductive cough	L	S	200×150	None	Large superior mediastinal mass
6	Sakai *et al.* (7)	2011	48	F	–	L	–	–	None	Mediastinal mass
7	Sayed *et al.* (8)	2013	45	F	Cough, dyspnea	L	S	120×120×80	None	Superior mediastinal mass extending into L upper thoracic region, displacing upper pole of L lung
8	Huang and Jiang (9)	2017	57	M	–	L	S	30×35	None	–
9	Galvaing *et al.* (10)	2018	72	M	Asymptomatic	L	S	66×42×56	None	–
10	Shen *et al.* (11)	2019	63	F	Asymptomatic	L	S	47×31	None	–
11	Cai *et al.* (3)	2019	43	M	Asymptomatic	L	S	61×106	None	Anterior mediastinal mass
12	Rappaport *et al.* (12)	1992	20	M	Asymptomatic	L	–	–	SVC, azygos, hemiazygos, L inferior pulmonary	Mediastinal widening
13	Haniuda *et al.* (13)	2000	63	F	Asymptomatic	L	S	30	None	–
14	Haniuda *et al.* (13)	2000	21	F	Asymptomatic	R	S	40	None	R superior mediastinal mass
15	Tsuji *et al.* (14)	2004	16	F	Asymptomatic	L, R	S (L), F (R)	110 (L), 40 (R)	None	Abnormal shadows on L & R superior mediastinum
16	Mikroulis *et al.* (15)	2010	60	M	Asymptomatic	R	F	–	None	Mediastinal widening
17	Dua *et al.* (16)	2011	42	F	Asymptomatic	L	S	70	None	Soft tissue mass in L hilar region, partially obscuring L cardiac border

Table 1 (*continued*)

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#	Ref.	Year	Age (yrs)	Sex	Clinical presentation	Venous aneurysms				Diagnostic findings
						BCV	Type	Size (mm)	Others	CXR
18	Hayashi *et al.* (17)	2011	33	F	Asymptomatic	L	–	60×45	None	–
19	Moncada *et al.* (18)	1985	23	M	Non-painful swelling at R sternoclavicular joint	L	–	25	None	Unremarkable
20	Akiba *et al.* (19)	2012	27	M	Cough	L	–	–	None	L mediastinal widening
21	Nakada *et al.* (20)	2015	43	M	Chest pain	L	F	–	None	Abnormal chest shadow
22	Gorenstein *et al.* (21)	1992	0 d	F	–	L	F	–	SVC, R internal jugular	Mediastinal mass
23	Bartline *et al.* (22)	2016	58	F	Pain, dyspnea, dysphagia, hoarseness	R	–	71	R internal jugular, R subclavian	–
24	Newell *et al.* (23)	1983	20	M	Nonspecific retrosternal chest pain, sometimes associated with epigastric pain	L	–	35	None	Mediastinal widening
25	Burkill *et al.* (28)	1997	21	F	Unrelated findings	L	S	–	None	Mediastinal widening
26	Davies and Roberts (32)	1998	50	F	Pain and swelling over R supraclavicular & shoulder area; dilated superficial veins	R	–	–	SVC	Mediastinal widening
27	Bansal *et al.* (33)	2010	42	F	Nonspecific pain in L infraclavicular region, dyspnea, palpitation	L	S	–	None	Superior mediastinal widening secondary to a mass
28	Buehler *et al.* (34)	2013	84	F	Back pain radiated to neck, nausea, vomiting	L	S	83×67	None	Large pericardiac density extending from below aortic arch to diaphragm
29	Lohrenz *et al.* (35)	2018	25	F	Nonproductive cough, dyspnea, thoracic pressure, pain in left arm, exacerbated when leaning forward	L	S	64–69	None	Well-defined, homogeneous mass in anterior mediastinum
30	Hosaka *et al.* (36)	2011	70	F	Hoarseness, worsening cough	L	S	40	None	–
31	Aggarwal *et al.* (37)	2017	20	M	Nonproductive cough	L	S	–	None	Anterior mediastinal mass

Table 1 (*continued*)

Table 1 (*continued*)

#	Ref.	Year	Age (yrs)	Sex	Clinical presentation	Venous aneurysms				Diagnostic findings
						BCV	Type	Size (mm)	Others	CXR
32	Pellizzari *et al.* (38)	2008	87	M	Unrelated findings	L	S	13×60×22	None	Heart shadow enlargement, no mediastinal widening noted
33	van der Vorst and Veger (39)	2019	74	M	–	L	S	70	None	–
34	Okay *et al.* (40)	1970	16	F	Asymptomatic	L	S	–	SVC	Mediastinal widening
35	Marmolya & Yagan (41)	1989	47	M	–	L	–	24	None	Isolated oval density in anterior mediastinum
36	Güney *et al.* (42)	2004	24	M	Lower neck mass that enlarged with Valsalva manoeuvre	L, R	–	–	R internal jugular	Mediastinal widening, anterior mediastinal mass

F, female; M, male; mo, month; d, day; L, left; R, right; BCV, brachiocephalic vein; S, saccular; F, fusiform; SVC, superior vena cava; CXR, chest X-ray; CT, computed tomography; MRI, magnetic resonance imaging.

tumor retraction (19).

Management and outcomes

While multiple treatment options are available, established guidelines regarding therapy for brachiocephalic vein aneurysms are lacking. Treatment is largely determined by clinical presentation, characteristics of the aneurysm, patient decisions, and surgical candidacy. Current treatment approaches include conservative management and surgery.

Conservative management

Conservative management was reported in 12/28 cases (43%) (*Table 2*).

This approach has been suggested as a reasonable option for patients who are asymptomatic with small, non-enlarging brachiocephalic vein aneurysms (6,14,16). The majority of patients treated conservatively had saccular brachiocephalic vein aneurysms (75%, 9/12 cases). The rest had either fusiform brachiocephalic vein aneurysms (17%, 2/12 cases) or the aneurysm type was not identified. The conservative approach is also recommended for patients who are poor surgical candidates (34) or those who do not wish to receive more invasive treatment (33). Upon presentation of thrombotic material, antithrombotic therapy should be discussed. Of the 12 patients who received conservative treatment, 4 (33%) had no complications, 2 (17%) required urgent surgery, and information on follow-up for the remaining 6 (50%) was not available.

Observation only

Conservative treatment with observation only, was reported in 7 cases (58% of patients who received conservative treatment). Of these patients, 3 had no thrombi (16,33,35), 1 had thrombus but was a poor surgical candidate (34) and the presence or absence of thrombi was not mentioned in 3 cases (14,18,23). At a 2 year (14) and 1 year follow-up (23), complications or dilation of the aneurysm were not observed in two cases (14,23). During the 2 year follow-up, one case experienced worsening of symptoms and required explorative surgery (35). Follow-up information was not mentioned for the remaining four cases (16,18,33,34).

Antiplatelet therapy

Two cases (17%) of antiplatelet therapy for brachiocephalic vein aneurysm have been described (15,38). One case was treated with ASA at 160 mg/day (15), while information on

Table 2 Conservative treatment approaches and outcomes of brachiocephalic vein aneurysms

#	Ref.	Year	Antithrombotic	Complications	Length of hospital stay	Follow-up
1	Tsuji *et al.* (14)	2004	None	None	–	2 year: dilatation of the aneurysm was not observed
2	Mikroulis *et al.* (15)	2010	Antiplatelet (ASA)	None	–	15 year: asymptomatic
3	Dua *et al.* (16)	2011	–	–	–	–
4	Moncada *et al.* (18)	1985	–	–	–	–
5	Newell *et al.* (23)	1983	–	–	–	1 year: no complications
6	Bansal *et al.* (33)	2010	–	–	–	–
7	Buehler *et al.* (34)	2013	–	–	–	–
8	Lohrenz *et al.* (35)	2018	No	Progression in thoracic discomfort and shoulder/arm pain; recurrent bronchopulmonary infection	–	Surgery needed
9	Hosaka *et al.* (36)	2011	Warfarin	None	–	1.5 months: aneurysm decreased in size, calcified along its periphery, reduced intraluminal thrombus (contrast-enhanced CT) 8 months: aneurysm and intraluminal thrombus sizes further decreased. Improved symptoms 1 year: plasma CRP within normal range, D-dimer decreased to 0.09 ug/mL
10	Aggarwal *et al.* (37)	2017	Low molecular weight heparin	Unexplained sudden onset syncope, cyanosis and respiratory distress	3 days	Surgery needed
11	Pellizzari *et al.* (38)	2008	Antiplatelet	–	–	–
12	van der Vorst and Veger (39)	2019	Direct oral anticoagulant (apixaban)	–	–	–

CT, computed tomography; CRP, C-reactive protein.

the antiplatelet drug and dosing regimen for the other case is not available (38). One patient was lost to follow-up (38) and the other was on antiplatelet treatment for 15 years and remained asymptomatic (15).

Anticoagulation

Anticoagulation with warfarin, low molecular weight heparin or direct oral anticoagulant (apixaban) have been reported in 3 cases in the management of brachiocephalic vein aneurysms (36,37,39). Of the 3 cases treated with an anticoagulant, 2 had thrombosed aneurysms (36,37) whereas 1 was continued on apixaban given pre-existing atrial fibrillation (39). One patient experienced successful reduction in size of the intraluminal thrombus and the aneurysm, as evaluated by contrast-enhanced CT at 1.5 and 8 months post-treatment. One patient treated conservatively with low-molecular weight heparin (37) developed sudden onset syncope, cyanosis and respiratory distress from the aneurysm, requiring emergency surgery. One patient was lost to follow-up (39).

Surgery

Surgery with aneurysmectomy and repair was performed in 57% of patients (16/28 cases) for brachiocephalic vein aneurysms that were symptomatic (19%, 3/16 cases) (5,8,22), saccular (69%, 11/16 cases) (1-11), expanding (12%, 2/16 cases) (6,22), or containing intraluminal thrombi (44%, 7/16 cases) (4-8,11,37) (*Table 3*).

Surgery was also performed to confirm diagnosis (12%, 2/16 cases) (20,35), to prevent possible major complications such as thromboembolism, rupture, or venous compression with subsequent obstruction (38%, 6/16 cases) (2-4,8,10,22), or to address aneurysmal complications (12%, 2/16 cases) (35,37).

Surgical approaches

Among the reported cases, median sternotomy was the most common surgical approach (56%, 9/16 cases) given its versatility and ease for use with cardiopulmonary bypass (CPB) (2,4,6,9-11,19,22,37), followed by thoracotomy (12%, 2/16 cases) (2,8) and thoracoscopy (6%, 1/16 cases) (35). CPB was established in 4 cases (25% of patients who received surgical treatment) to provide clear anatomic details and mobilization of the aneurysm, prevent excessive blood loss, reduce the risk of embolization, and allow for decompression of the cerebral venous system in preparation for superior vena cava cross-clamping, if necessary (4,6,11,22). Endovascular treatment is also becoming a new therapeutic approach for patients with brachiocephalic vein aneurysms, as one patient (6%) was successfully treated with stent placement and coil embolization of the left brachiocephalic vein (3).

Operative outcomes

Brachiocephalic vein aneurysms were successfully resected in 81% of patients (13/16 cases). Intra-operative complications were reported in 3 cases (19%) (1,5,22,25,26). One patient died during an operation due to cardiac and respiratory failure (1). Nitta *et al.* reported another case where the surgery was discontinued due to friability of a large aneurysm (5). To reduce the size of the aneurysm, a thymectomy with left subclavian and jugular veins ligation was performed instead. Bartline and colleagues also described a case of intra-operative right heart failure that required implantation of a temporary right ventricular assist device (22). Post-operative complications were reported in two cases (13%), including left phrenic nerve paralysis (20) and right heart failure requiring hospitalization (22).

Patients spent 3 to 58 days in the hospital after surgical resection of brachiocephalic vein aneurysms (2,3,5,10,20,35,37). Post-operative anticoagulants (19% of patients) included heparin (4), low molecular weight heparin (35), and warfarin (3,4). One patient had heparin with bridging to warfarin for 3 months following surgery (4). One patient was on low molecular weight heparin once daily for 7 days post-operatively (35). And another patient received warfarin for 3-6 months following endovascular treatment of the brachiocephalic vein aneurysm (3).

The majority of patients (69%, 11/16 cases) had completion of follow-up. No complications or recurrence were noted in 8 cases (50%) (2,8-11,20,22,35). Symptoms were resolved in 3 cases (19%) (8,11,37). One patient died of chronic respiratory failure (26). Endovascular repair demonstrated aneurysmal shrinkage on chest CT 18 months after intervention, although increased intraluminal thrombus size was observed (3).

The prognosis of brachiocephalic vein aneurysms is good post resection with no reported cases of recurrence.

Conclusions

Brachiocephalic vein aneurysms are rare vascular lesions that often present asymptomatically as a widening of the mediastinum on the chest radiograph. Surgical aneurysmectomy is indicated in patients with symptomatic, saccular, expanding brachiocephalic vein aneurysms; those containing intraluminal thrombi; and those presenting with complications such as recurrent thromboembolism, rupture, or mass effect on surrounding structures. Surgical outcomes are acceptable with favorable prognosis post-resection and

Table 3 Surgical treatment approaches and outcomes of brachiocephalic vein aneurysms

#	Ref.	Year	Surgical approach	Cardiopulmonary bypass (CPB) required	Method of repair	Anti-thrombotic	Complications	Hospital stay	Follow-Up
1	Harris (1)	1928	Transverse incision across the R sternomastoid 1in above the clavicle	–	Aneurysm was resected	–	Patient died of intra-operative cardiac and respiratory failure	–	–
2	Yokomise *et al.* (2)	1990	Sternotomy combined with 5th intercostal thoracotomy	–	Aneurysm was resected. The proximal end of the resection line was closed with 5-0 prolene suture	–	–	1 month	3 weeks: no stenosis noted (angiography)
3	Pasic *et al.* (4)	1995	Sternotomy	Partial CPB with cannulation in the ascending aorta and proximal LBCV	Aneurysm was opened longitudinally. Aneurysmal wall partially resected. Mediastinal venous system reconstructed using rest of aneurysmal wall and running 4-0 polypropylene sutures	Low-dose heparin, warfarin	None	–	–
4	Nitta *et al.* (5,25,26)	2005, 2006, 2008	–	–	1st attempt: resection of LBCV aneurysm, discontinued due to complication; 2nd attempt: thymectomy, left subclavian vein ligation and jugular vein ligation	–	Surgery discontinued due to extremely large aneurysm that bled easily	58 days	35 days: respiratory support with a ventilator not needed 51 days: reduction of LBCV aneurysm, development of collateral vein (angiography) 3 months: recurrent respiratory arrest. LBCV aneurysm with large collateral veins surrounding and enclosing the trachea. SVC aneurysm of the same size (which turned out to be RBCV aneurysm on autopsy) (angiography) 22 months: death due to chronic respiratory failure
5	Hosein *et al.* (6)	2007	Sternotomy	Yes	Aneurysm was opened longitudinally. Aneurysmal wall was resected. The underside of LBCV was reconstructed using a bovine pericardium patch	–	None	–	–
6	Sakai *et al.* (7)	2011	–	–	Aneurysm was resected	–	None	–	–
7	Sayed *et al.* (8)	2013	Left thoracotomy	No	Aneurysm was excised including a rim of normal tissue of the BCV surrounding the neck of the aneurysm	–	None	–	4 months: asymptomatic. No recurrence (angiography)

Table 3 (*continued*)

Table 3 (*continued*)

#	Ref.	Year	Surgical approach	Cardiopulmonary bypass (CPB) required	Method of repair	Anti-thrombotic	Complications	Hospital stay	Follow-Up
8	Huang and Jiang (9)	2017	Sternotomy	–	Aneurysm was resected. BCV was reconstructed with 5-0 prolene sutures	–	None	–	2 years: no complications
9	Galvaing *et al.* (10)	2018	Sternotomy	No	Thymectomy was performed. Aneurysm was dissected. Its neck was identified and resected using an endostapler with a vascular load	–	None	3 days	3 months: patient recovered completely from the procedure; no abnormalities noted (contrast-enhanced CT)
10	Shen *et al.* (11)	2019	Sternotomy	No	Aneurysm was opened longitudinally– and resected. The defect on the underside of the BCV was closed by running 6-0 polypropylene sutures		None	–	1.5 years: asymptomatic, no recurrence noted (contrast-enhanced CT)
11	Cai *et al.* (3)	2019	Endovascular	–	Self-expanding stents were placed across the aneurysm. 2 interlock coils were inserted to embolize the L internal jugular vein	Warfarin	–	1 week	1 month: complete thrombus within aneurysm sac (contrast-enhanced CT) 3-6 months: increased blood flow within aneurysm sac. Anticoagulant therapy discontinued 12 months: complete thrombus formed within aneurysm sac, intraluminal thrombus formed around the stents 18 months: aneurysm decreased in size, intraluminal thrombus increased. Patient was asymptomatic, no pulmonary embolism (pulmonary CT angiography)
12	Akiba *et al.* (19)	2012	Sternotomy	–	Total thymectomy combined with aneurysm resection. Remaining BCV was closed with 5-0 prolene suture	–	None	–	–
13	Nakada *et al.* (20)	2015	L-shaped sternotomy with a left-sided cervical collar incision	–	Partial resection of the LBCV aneurysm using a stapler	–	Post-operative left phrenic nerve paralysis	9 days	5 months: no evidence of recurrence or further enlargement of the BCV

Table 3 (*continued*)

Table 3 (*continued*)

#	Ref.	Year	Surgical approach	Cardiopulmonary bypass (CPB) required	Method of repair	Anti-thrombotic	Complications	Hospital stay	Follow-Up
14	Bartline *et al.* (22)	2016	Sternotomy	Yes	Aneurysm was resected. Internal jugular vein was ligated. Femoral cryopreserved vein conduit was used for venous reconstruction	–	Intraoperative acute right HF, requiring placement of a temporary RVAD; right HF 2 months post-operation, requiring hospital admission	–	2 months: patency of the axillary, subclavian, and cryopreserved vein conduit (duplex ultrasound)
15	Lohrenz *et al.* (35)	2018	Minimally invasive thoracoscopy	No	Aneurysm was drained by local compression followed by cross-clamping of the aneurysm base. Aneurysm was resected and repaired by endostapler	Low molecular weight heparin	None	1 week	Post-operative: normal flow in LBCV (MRI)
16	Aggarwal *et al.* (37)	2017	Sternotomy	Yes	LBCV was ligated into SVC. Aneurysm was opened, thrombus was removed. Aneurysmal wall was resected	–	None	3 weeks	6 months: asymptomatic

L, left; R, right; BCV, brachiocephalic vein; SVC, superior vena cava; CT, computed tomography; MRI, magnetic resonance imaging; RVAD, right ventricular assist device; HF, heart failure.

no recurrence reported.

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Footnote

Conflicts of Interest: All authors have completed the ICMJE uniform disclosure form (available at http://dx.doi.org/10.21037/jtd.2020.04.39). The authors have no conflicts of interest to declare.

Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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