

Position of valves within the subclavian and axillary veins

Halil Celepci and Erich Brenner, MD, PhD, MME, *Innsbruck, Austria*

Background: The aim of this explorative morphologic study was to determine the position and frequency of the valves in the axillary and subclavian veins.

Methods: The position and frequency of the valves in the subclavian and axillary veins were studied macroscopically in 59 limbs from 30 cadavers. We measured in situ with a measuring tape, starting from the venous angle toward the initiation of the axillary vein. All cadavers were bequeathed by informed consent.

Results: A terminal valve existed in all subclavian veins within the range of 0.0 to 27.5 mm (mean: left, 13.87 mm; right, 9.78 mm) distally to the venous angle; a second valve existed in one left and one right subclavian vein at a distance of 30.0 and 30.5 mm, respectively. All left axillary veins had a "most proximal" valve (mean, 103.4 mm), 73.3% also possessed a second valve (mean, 140.48 mm), and 16.7% had a third valve (mean, 153.9 mm). All right axillary veins possessed at least one valve (mean, 100.07 mm), 75.86% had a second valve (mean, 134.55 mm), 34.48% also had a third valve (mean, 157.30 mm), and 10.3% had a fourth valve (mean, 140.0 mm).

Conclusions: All of the axillary and subclavian veins in our specimens possessed at least one valve. All the valves in the subclavian veins were concentrated to the proximal half, resulting in a valveless distal half. The subclavian vein rarely had a second valve. The valves in the axillary veins were located in the distal half, resulting in a valveless proximal half. The axillary vein can have one to four valves. No relation was evident between the frequency of the valves and the age of the donors when they died. Many other factors may influence the frequency of the valves in the axillary vein. (*J Vasc Surg* 2011;54:70S-6S.)

Clinical Relevance: Venous valves within subclavian veins could be a barrier for catheterization. The risk of harming these valves during catheterization can be minimized when the exact position and the frequency of these valves are known. Axillary vein transfer can be successfully performed in trabeculated veins, and here, as well the knowledge of the exact position and the frequencies of the valves within the axillary vein, will increase surgical outcome. Furthermore, these valves have an important role in establishing an appropriate extrathoracic arteriovenous pressure gradient that is necessary for forward blood flow during cardiopulmonary resuscitation and other states with high intrathoracic pressure.

The axillary and the subclavian vein are both important doorways for central venous access and are used, for instance, for the placement of central venous catheters or pacemaker leads. Placement of these catheters or leads may be complicated by thrombosis of the related vein. Furthermore, both veins are sometimes affected by an effort-related venous thrombosis.¹ Because thrombi form in the sinuses of venous valves,² the valves of the axillary and subclavian veins are also of interest. In addition, the valves of the internal jugular and especially subclavian veins could be a barrier for venous catheterization. The risk of harming these valves during venous catheterization can be mini-

mized if the exact position and the anatomic features of the valves are known.³

Another important aspect of the axillary vein is that sections of vein containing a proper venous valve can be used for transplantation. Axillary vein transfer can, for instance, be successfully performed in trabeculated veins of the leg.^{4,5} Instead of an axillary vein transfer in trabeculated veins, it is also possible to perform a cryovalve insertion. Compared with autologous vein transfer, however, cryovalve insertion is associated with high morbidity, a high occlusion rate, poor cumulative midterm rate of the patent graft with competent valve, and poor clinical results.⁶

GENERAL ASPECTS OF VENOUS VALVES

Venous valves are formed as a duplication of the intima, strengthened by collagenous and elastic fibers, and covered on both surfaces with endothelium. On the luminal surface, the cells are arranged longitudinally, and on the other surface of the valve, next to the vein wall, the cells are arranged transversely.⁷ Venous valves can act as modulators of the blood flow,⁸ which open when blood passes and close by the decreasing flow velocities rather than by a reflux into the sinuses of the valve.⁹

The two main factors in directing the flow of blood in veins toward the heart are the small positive (or even negative) pressures obtained within the thorax and the

From the Division of Clinical and Functional Anatomy, Department of Anatomy, Histology and Embryology, Innsbruck Medical University.

Competition of interest: none.

This work was presented at the Second Annual Meeting of the German Society of Phlebology, Aachen, Germany, on Nov 12, 2010.

Reprint requests: Prof Dr Erich Brenner, MME (Bern), Division of Clinical and Functional Anatomy, Department of Anatomy, Histology and Embryology, Innsbruck Medical University, Müllerstraße 59, 6020 Innsbruck, Austria (e-mail: erich.brenner@i-med.ac.at).

The editors and reviewers of this article have no relevant financial relationships to disclose per the JVS policy that requires reviewers to decline review of any manuscript for which they may have a competition of interest.

0741-5214/\$36.00

Copyright © 2011 by the Society for Vascular Surgery.

doi:10.1016/j.jvs.2011.06.083

compressing action of contracting muscles on the veins. In the limbs, the effectiveness of the muscle pump, which might under certain circumstances drive blood toward the periphery rather than toward the heart, is assured by the presence of valves in the veins. These allow free passage of blood toward the heart but impede passage of blood in the reverse direction.¹⁰ If the valves do not close sufficiently (valve insufficiency), the venous blood has the tendency to flow back.

The frequency of venous valves as well as the number and form of their cusps are closely related to two essential factors:

1. the structural configuration of the body segments, which differ in the limbs, head and neck, and great cavities of the body; and
2. the vein types, which may be epifascial (or superficial) and subfascial (deep) veins.⁷

In children, venous valves are reported to be generally more frequent than in adults,⁷ and valve density in the deep concomitant veins of the limbs at all ages is higher than in the superficial veins.

It is generally assumed that the veins of the limbs have the most constant valvular geometry. A common principle seems to be obvious: the density of the venous valves decreases gradually from the distal toward the proximal parts of the limbs. The distance between two valves varies proportionally with the length of the limb.⁷

Subclavian vein. The subclavian vein originates at the level of the costo-coracoclavicular space, under the middle portion of the clavicle, and is the continuation of the axillary vein. This vein collects the venous circulation of the arm, the axilla, part of the neck, the thoracic wall, and the scapular region.¹¹ Venous blood of the shoulder girdle flows via pectoral, scapular, and occasionally, thoracoacromial veins directly into the subclavian vein. All the remaining veins of the arm are either direct or indirect tributaries of the axillary vein.¹² Nearly all of the branches that open into the subclavian vein are furnished with a valvular apparatus.¹¹

In the excellent study by Anderhuber,¹³ in which he investigated 97 cadavers, he described the subclavian vein as follows: It has an average length of 4 cm, runs above the superior face of the first rib in a medial and slightly ventral direction, and joins the internal jugular vein. This junction is also named the venous angle. Valves within the subclavian vein are found all along the length of the vessel. Only a few of them reach the venous angle.¹³

Axillary vein. The axillary vein is described as the confluence and continuation of the basilic, cephalic, and brachial veins. It starts at the lower border of the tendon of the pectoralis major muscle and ends at the outer margin of the first rib.¹⁴ It is close to the axillary artery, being first medial to it and then inferior to it higher up in the axilla. The axillary vein receives the brachial veins, two or more accompanying veins of the brachial artery near its commencement, and the cephalic vein near its termination.¹⁵

Study aims. Although there are several studies about the subclavian vein, almost no data are available about the valves of the axillary vein. The principal aim of our explorative morphologic study was to determine the exact position and the frequency of valves within the axillary and subclavian veins. Another aim was the structure of these valves, whether unicuspid, bicuspid, or tricuspid.

According to the previous findings, we assume that the subclavian vein usually possesses one, but sometimes even two sufficient venous valves. We expect most valves within the right subclavian vein will be located at a more or less constant distance of 1 to 2 cm distally of the confluence of the internal jugular vein with the subclavian vein. The distribution of the valves at the left side is supposed to be slightly wider. The axillary vein might have one to three relatively constant venous valves.

MATERIAL AND METHODS

From October to December 2009, we dissected the axillary and subclavian veins from 30 cadavers (20 women, 10 men), which had been fixed with formaldehyde and phenolic acid,¹⁶ from the venous angle to the lower border of the tendon of the pectoralis major muscle during the period of the regular dissection course.

All cadavers derived from the Division for Clinical and Functional Anatomy of Innsbruck Medical University were assigned to a specific use for the anatomic dissection course of students in their third term. All donors bequeathed their bodies to the division by informed consent before their deaths.¹⁷

The donors were a mean age of 83.9 years (range, 61-97 years) at death, and their mean height was 164.19 cm (range, 136-182 cm). In one cadaver, metastasis of colon cancer had destroyed the anatomy in the right axillary region so that we could not get the information about the axillary and subclavian veins. Thus, we dissected 59 arms from 30 specimens. The cadavers were pre-dissected by the second-year students, who mainly removed the skin but did not expose the veins.

First, we carefully exposed both veins, marked their borders, measured the length of the veins in situ, and documented these values. Afterward, we longitudinally opened the veins in situ with scissors, beginning at the venous angle toward the lower border of the tendon of the pectoralis major muscle in order not to damage the valves so that we could easily identify the valve structure. We cleaned the lumen of the veins with both a forceps and diluted formaldehyde and identified the valves macroscopically. We performed the measurement in situ with a measuring tape, starting from the venous angle toward the initiation of the axillary vein. We measured the distances of the valves from the venous angle and documented them on our test sheet.

The dissection and initial data acquisition were mainly performed by the first author (H.C. with the help of Caglayan Demirel [C.D.]). Each length was measured at least twice (H.C. and C.D.), and the mean values of these two measurements were used for further analysis. The

Table I. Left subclavian veins

Valves, No.	Frequency (%)	Cumulative %
1	29 (96.7)	96.7
2	1 (3.3)	100.0
Total	30 (100.0)	

Table II. Valves of the left subclavian veins: Descriptive statistics

Valve	No.	Distance to the venous angle, mm		
		Min	Max	Mean \pm SD
First valve	30	2.5	27.5	13.867 \pm 6.3517
Second valve	1	30.5	30.5	30.500 \pm . . .

SD, Standard deviation.

acquired data were finally controlled by the second author (E.B.) The inter-rater reliability was tested by calculating the Cronbach α for all metric variables ranging from 0.979 to 0.998. The statistical analysis of data was performed by SPSS 17.0.0 software (SPSS Inc, Chicago, Ill) and Excel 2007 (Microsoft Corp, Redmond, Wash).

Definitions. For the following presentation of results, we labeled the most proximal valve, that is, the final (or in the case of the subclavian vein the terminal) valve in the direction of blood flow, of each vein as the “first” valve, the next distal valve as the “second” valve, and so on.

RESULTS

Subclavian vein. The mean lengths were 34.9 mm (range, 23.5-44.5 mm) for the left subclavian vein and 33.6 mm (range, 21-47 mm) for the right; the mean difference in length was not significant ($P = .343$). Furthermore, we detected no significant sex differences for left (mean difference, 2.55 mm; $P = .221$) or right subclavian veins (mean difference, 2.97 mm; $P = .249$).

The “first” valve was present in all 30 left subclavian veins within 2.5 to 27.5 mm distally of the venous angle. Only in one of these veins (3.3%) we could identify a “second” valve, at a distance of 30.5 mm to the venous angle. We found a “first” valve in all 29 right subclavian veins within 0.0 mm to 19.5 mm. Again, one right subclavian vein had a “second” valve, with a distance of 30 mm to the venous angle. Those two “second” valves were found in different female cadavers: one at the right side and the other at the left side. Detailed data are presented in Tables I-IV and in the Fig.

Of the 30 “first” left valves, 28 (93.3%) were bicuspid and 2 (6.7%) were tricuspid. The only “second” left valve we found also had two cusps. At the right subclavian vein, all of the “first” valves were bicuspid and the only “second” valve was unicuspid.

Axillary vein. The mean length of the axillary veins was 150.1 mm (range, 120.0-174.5 mm) on the left side

Table III. Right subclavian veins

Valves, No.	Frequency (%)	Cumulative %
1	28 (96.6)	96.6
2	1 (3.4)	100.0
Total	29 (100.0)	

Table IV. Valves of the right subclavian veins: Descriptive statistics

Valve	No.	Distance to the venous angle, mm		
		Min	Max	Mean \pm SD
First valve	29	0.0	19.5	9.776 \pm 5.6704
Second valve	1	30.0	30.0	30.000 \pm . . .

SD, Standard deviation.

and 149.0 mm (range, 124.5-175.5 mm) on the right side; their mean difference in length was not significant ($P = .673$). The average length of left axillary veins was equal in men and women (mean difference, 0 mm); on the right side there was a mean difference of 0.139 mm ($P = .383$).

All of the left axillary veins had a “first” valve within 50.0 to 139.0 mm distally to the venous angle. We identified a “second” valve in 22 specimens. The closest “second” valve to the venous angle was a distance of 96.0 mm and the farthest one was 205.5 mm to the venous angle. Five left axillary veins possessed a “third” valve within 115.0 to 173.5 mm. Detailed data are presented in Tables V-VIII and in the Fig.

In summary, of the 30 left axillary veins, 8 possessed only 1 valve, 17 (56.7%) had 2, and 5 veins (16.7%) had 3 valves. Of the “first” left valves, 27 (90%) were bicuspid, 2 (6.7%) were tricuspid, and 1 (3.3%) was unicuspid. All of the “second” and “third” left valves were bicuspid.

One valve was present in 7 of the 29 right axillary veins (24.1%); we found a “second” valve in 12 (41.4%), a “third” in another 7 veins (24.1%), and a “fourth” valve in 3 veins (10.3%). Of the “first” right valves, 27 (93.1%) were bicuspid and 2 (6.9%) were unipartite. Moreover, all of the “second,” “third,” and “fourth” valves were bicuspid.

The “first” valves in the right axillary veins were located within 29.0 to 140.0 mm (standard deviation \pm 25.739) distally to the venous angle. We found the closest “second” right valve to the venous angle at 85.0 mm and the farthest was at 185.0 mm. The “third” valves were a mean distance of 157.3 \pm 24.757 mm (range, 116.5-190 mm). Three right axillary veins had a “fourth” valve at a distance to the venous angle of 140.0, 159.5, and 179.5 mm. Those three axillary veins were in the right arms of female specimens.

Valve allocation. To generalize the distribution of the valves in the investigated veins, we divided these into segments and allocated the valves to each segment. The segments of the subclavian vein were defined as follows:

Segment 1: \leq 10 mm distally to the venous angle

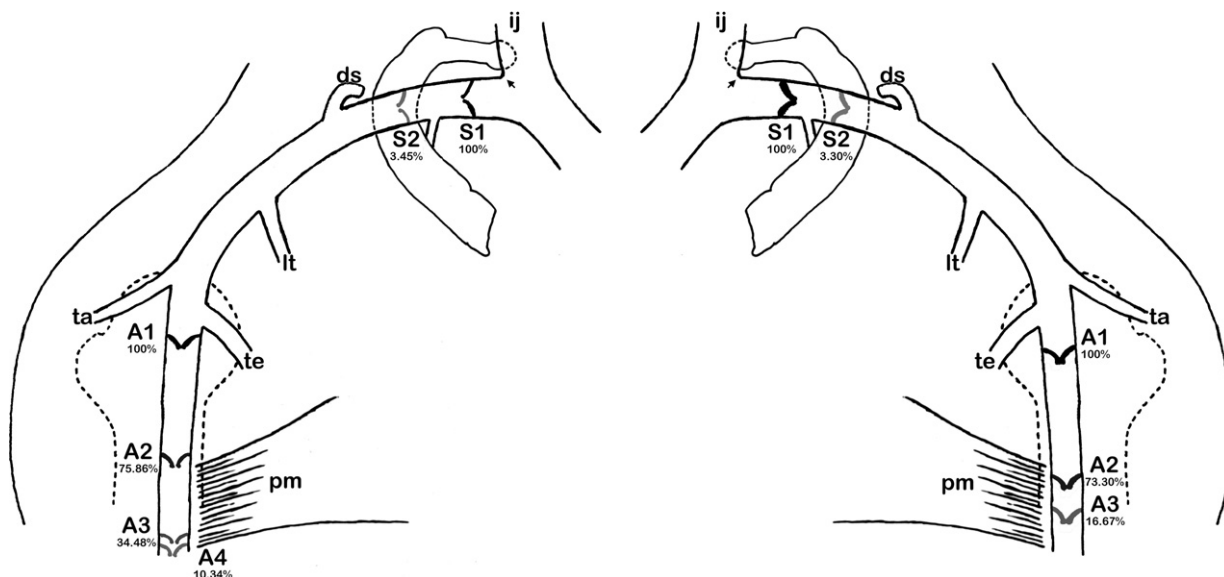


Fig. Schematic shows the valves in the subclavian vein (S1, S2), the valves within the axillary vein (A1 to A4), and the confluence of the subclavian vein with the internal jugular vein (venous angle, arrow). Also shown, but not labeled, are the contours of the first ribs and the proximal humerus, and internal thoracic veins (hiding below the first ribs). Percentages indicate the prevalence of the respective valve. ds, Dorsal scapular vein; ij, internal jugular vein; lt, lateral thoracic vein; pm, pectoralis muscle; ta, thoracoacromial vein; te, thoracoepigastric vein.

Table V. Left axillary veins

No. of valves	Frequency (%)	Cumulative %
1	8 (26.7)	26.7
2	17 (56.7)	83.3
3	5 (16.7)	100.0
Total	30 (100.0)	

Table VI. Valves of the left axillary veins: Descriptive statistics

Valve	No.	Distance to the venous angle, mm		
		Min	Max	Mean ± SD
First valve	30	50.0	139.0	103.350 ± 25.2973
Second valve	22	96.0	205.5	140.477 ± 30.6091
Third valve	5	115.0	173.5	153.900 ± 23.5807

SD, Standard deviation.

Segment 2: 10 mm < second segment ≤20 mm distally to the venous angle

Segment 3: 20 mm < third segment ≤30 mm distally to the venous angle

Segment 4: 30 mm < fourth segment < the outer margin of the first rib

We limited the segments at a 1-cm interval each, relying on Anderhuber's investigation.¹³ According to this author, most of the right-sided valves of the subclavian vein are

Table VII. Right axillary veins

Valves, No.	Frequency (%)	Cumulative %
1	7 (24.1)	24.1
2	12 (41.4)	65.5
3	7 (24.1)	89.7
4	3 (10.3)	100.0
Total	29 (100.0)	
Missing	1	
Total	30	

Table VIII. Valves of the right axillary veins: Descriptive statistics

Valve	No.	Distance to the venous angle, mm		
		Min	Max	Mean ± SD
First valve	29	29.0	140.0	100.069 ± 25.7386
Second valve	22	85.0	185.0	134.545 ± 23.3819
Third valve	10	116.5	190.0	157.300 ± 24.7568
Fourth valve	3	140.0	179.5	159.667 ± 19.7505

SD, Standard deviation.

situated within 1 to 2 cm distal to the venous angle. The valves at the left side are distributed more widely (1 to 3 cm distal to the venous angle; Fig).

In 9 cases (30%), the "first" valves of the left subclavian veins were located in segment 1, in 16 (53.3%) in segment 2, and in 5 (16.7%) in segment 3. The only "second" left valve was located in segment 4.

At the right side, the distribution was slightly different: 16 of the 29 “first” valves (55.2%) were localized in segment 1, and the rest of the valves (44.8%) were in segment 2. The only “second” right valve was situated in segment 3.

We arbitrarily divided the axillary vein into seven segments to make an easier generalization of the distribution of the valves. We tried to apply a new standard and because the distribution of the valves was wider in the axillary vein, we thought that 3-cm segments would be ideal. The segments were therefore described as follows:

Segment 1: Outer margin of the first rib < first segment ≤ 40 mm distally to the venous angle

Segment 2: 40 mm < “second” segment ≤ 70 mm to the venous angle

Segment 3: 70 mm < third segment ≤ 100 mm to the venous angle

Segment 4: 100 mm < fourth segment ≤ 130 mm to the venous angle

Segment 5: 130 mm < fifth segment ≤ 160 mm to the venous angle

Segment 6: 160 mm < sixth segment ≤ 190 mm to the venous angle

Segment 7: 190 mm < seventh segment < lower border of the pectoralis major muscle

Left axillary vein. We did not identify any “first” left valves in segment 1 (Fig). Only 4 of the “first” left valves (13.3%) were located in segment 2, 7 (23.3%) in segment 3, 14 (46.7%) in segment 4, and 5 (16.7%) were in segment 5.

The “second” valves in the left axillary veins were spread more: 3 valves (13.6%) were in segment 3, 6 (27.3%) in segment 4, 8 (36.4%) in segment 5, 2 (9.1%) in segment 6, and 3 (13.6%) were in segment 7.

Of the 5 “third” left axillary valves, 1 was in segment 4, 2 were in segment 5, and 2 were in segment 6.

Right axillary vein. We found 29 “first” right valves (Fig) distributed as follows: segment 1, 1 valve (3.4%); segment 2, 3 valves (10.3%); segment 3, 8 valves; segment 4, 13 valves (44.8%); and segment 5, 4 valves (13.8%).

One “second” right valve (4.5%) was in segment 3. In segments 4 and 5, we found 9 valves (40.9%) each. The remaining three “second” valves (13.6%) were found in segment 6.

One of the 10 “third” right valves (10%) was in segment 4, 4 (40%) were in segment 5, and 5 (50%) were in segment 6.

Two of the three “fourth” right valves were in segment 5, and one was in segment 6.

DISCUSSION

Frequency of the valves. Data on the presence of valves in the subclavian vein are rare, for the axillary vein, even rarer. In an autopsy study of venous valves in the subclavian vein and internal jugular veins, Harmon and

Edwards¹⁸ reported that valves were absent in 2% of subclavian veins and were absent more commonly in left-sided than right-sided veins. Another study found that all of the subclavian veins possessed venous valves.³

Anderhuber¹³ stated that valves were found along the whole length of subclavian veins. Only a few were situated at the venous angle. In rare cases, two valves existed. He found no valves in 9%, and the absence rate was higher at the right side.¹³

According to Franklin,¹⁹ Haller and Houz e found one valve and Piersol identified two valves in the subclavian vein, one at the venous angle and the other at the end of the subclavian vein. One to three venous valves have been reported for the axillary vein.^{7,19}

The present study found valves in 100% of the subclavian and axillary veins. So we can confirm the findings of Kiray et al.³ We found 29 of the 30 left subclavian veins (96.7%) had one valve and the 30th vein had two valves. One valve was present in 28 of the investigated 29 right subclavian veins, and the last vein had also two valves. Of the total 30 axillary veins at the left side, 8 (26.7%) had 1 valve, 17 (56.7%) had 2, and 5 (16.7%) had 3. On the right side, 7 of the axillary veins (24.1%) had 1 valve, 12 (40%) had 2, another 7 (24.1%) had 3, and the remaining 3 veins (10.3%) had 4.

Position of the valves. Anderhuber¹³ found valves along the entire length of the subclavian veins. Von Bardeleben had suggested two hypotheses about the position of the venous valves at the end of the 19th century: (1) the intervalvular distance is almost constant, and (2) valves exist immediately distal to the venous roots.

Bleicher and Weber,²⁰ Ogo,²¹ Nemoto,²² and Shima et al²³ reported that the intervalvular distance was not constant and that there were valves distal to the orifices of the venous roots.²⁴ From our investigations, we can easily reaffirm that the distance between the valves in the subclavian and axillary veins is not constant; quite the contrary, the intervalvular distance is almost always different.

In their study of the position of the venous valves, Kiray et al³ found that the valves of the subclavian veins had a mean distance of 21.7 mm (range, 13-36.5 mm) to the venous angle. Other investigators reported that in every case the valves in the subclavian veins were localized ≤ 40 mm and that the mean distance to the junction with the internal jugular vein was 17 mm. The right-sided valves were located closer to the venous angle than the valves at the left side.¹⁸ Anderhuber found that most valves within the right subclavian vein were located at more or less a constant distance of 10 to 20 mm distally of the venous angle. The distribution of the valves at the left side was slightly wider.¹³

In our study the mean distance to the venous angle of the valves was 13.87 ± 6.351 mm in the left subclavian vein and 9.78 ± 5.670 mm in the right subclavian vein. Some of the findings of Anderhuber could be confirmed by our study. We also got similar results concerning the distribution of the valves at the left subclavian vein. According to our data, the distribution at the left side was also slightly

wider than at the right side, and 70% of the left valves were located at a distance of 10 to 30 mm distally to the venous angle. At the right side, the venous valves were located within 20 mm in every case.

Unfortunately, we could not find any investigations detailing the position of the venous valves within the axillary vein. This was most surprising, because the axillary vein is used for transfer surgery.⁴

Structure of the valves. The structure of the subclavian vein has been reported in many studies and was most commonly bicuspid, occasionally unicuspid, and rarely tricuspid.^{3,7,11,13,18,19} According to Franklin,¹⁹ a single valve may have from one to five cusps, but the most frequent form is the bicuspid valve.

In the present study, of the 61 identified valves in the subclavian veins, 58 valves (95.1%) were bicuspid, 1 (1.6%) was unicuspid, and 2 (3.3%) were tricuspid. Because the absolute frequency of the unicuspid and tricuspid valves was small, it is difficult to compare their results. But because of the high absolute amount of the bicuspid valves it is much easier to make a comparison. So, generally speaking, we had similar results as many other investigators. We were, again, unable to find any data to discuss the structures of the valves in the axillary vein.

We can easily verify our hypotheses concerning the subclavian vein, whereas the findings about the axillary vein were slightly different. We expected one to three valves in the axillary vein, but in 3 of the 59 investigated axillary veins (5.08%) we also found a “fourth” valve.

This study has certain limitations. We did not investigate the functional aspects of the valves, such as competency within the axillary and subclavian veins. This would have been quite difficult, because for determining the position of the valve, the vein could not be removed from the body and opened. For determining the valvular competence under standardized settings it would be necessary to remove the vein from its topographic context, and of course, the veins could not be opened. Furthermore, we did not investigate cusp orientation in relation to the skin.

Another possible bias is that the deceased donors were elderly (age ≥ 61 years). This might make it difficult to compare our results with those of other studies that have assumed a general reduction in the number of valves by increasing age.⁷ In this study, we could not test for a correlation between the age of the donor and the frequency of the venous valves to support this assumption.

CLINICAL AND FUNCTIONAL CONSIDERATIONS

The assumption that there is a relation between the existence of venous valves and the formation of thrombi^{2,25} leads to the conclusion that a higher number of valves increases the risk of thrombosis. This risk might be aggravated by an unintentional damage, especially of additional subclavian valves, by a central venous access.

Axillary vein transfer can be successfully performed in trabeculated veins, but this is not a very frequent interven-

tion.⁵ In that study, 20 of 21 procedures resulted in an initially competent valve, but the situation worsened within the follow-up period to, finally, only 40% competent valves. Here the knowledge of the exact position and the frequencies of the valves within the axillary vein can help to increase the long-term outcome, for instance, by selecting the best fitting valve for the donor site.

Another clinical application of our results deals with at least the valves within the subclavian vein, which are discussed for being important in establishing an appropriate extrathoracic arteriovenous pressure gradient necessary for forward blood flow during cardiopulmonary resuscitation and other states with high intrathoracic pressure.²⁶

We gratefully acknowledge Caglayan Demirel for his excellent help in dissecting the specimens.

AUTHOR CONTRIBUTIONS

Conception and design: HC, EB
Analysis and interpretation: HC, EB
Data collection: HC
Writing the article: HC, EB
Critical revision of the article: HC, EB
Final approval of the article: HC, EB
Statistical analysis: HC
Obtained funding: Not applicable
Overall responsibility: EB

REFERENCES

1. Sanders RJ, Haug C. Subclavian vein obstruction and thoracic outlet syndrome: a review of etiology and management. *Ann Vasc Surg* 1990;4:397-410.
2. Kyrle PA, Eichinger S. Deep vein thrombosis. *Lancet* 2005;365:1163-74.
3. Kiray A, Güvençer M, Arman C, Korman E, Ergür I, Karabay Ö, et al. Vena jugularis interna ve vena subclavia'nin Kapaklarının Özellikleri. *Dokuz Eylül Ü Tıp Fak* 2005;19:67-75.
4. Raju S, Neglén P, Doolittle J, Meydrech EF. Axillary vein transfer in trabeculated postthrombotic veins. *J Vasc Surg* 1999;29:1050.
5. Kabbani L, Escobar GA, Mansour F, Wakefield TW, Henke PK. Longevity and outcomes of axillary valve transplantation for severe lower extremity chronic venous insufficiency. *Ann Vasc Surg* 2011;25:496-501.
6. Neglén P, Raju S. Venous reflux repair with cryopreserved vein valves. *J Vasc Surg* 2003;37:552-7.
7. Maros T. Data regarding the typology and functional significance of the venous valves. *Morphol Embryol (Bucur)* 1981;27:195-214.
8. Mühlberger D, Morandini L, Brenner E. An anatomical study of femoral vein valves near the saphenofemoral junction. *J Vasc Surg* 2008;48:994-9.
9. Lurie F, Kistner RL, Eklof B, Kessler D. Mechanism of venous valve closure and role of the valve in circulation: a new concept. *J Vasc Surg* 2003;38:955-61.
10. Hollinshead WH. *Textbook of anatomy*. 3rd ed. Philadelphia: Harper & Row; 1974.
11. Calen S, Pommereau X, Gbikpi-Benissan AM, Videau J. Morphologic and functional anatomy of the subclavian veins. *Surg Radiol Anat* 1986;8:121-9.
12. Leonhardt H, Tillmann B, Zilles K, editors. *Topographie der Organsysteme, Systematik der peripheren Leitungsbahnen*. 20th ed. Stuttgart: Thieme; 1988.
13. Anderhuber F. Venenklappen in den Grossen Wurzelstämmen der vena cava superior. *Acta Anat [Basel]* 1984;119:184-92.

14. Dauber W. Feneis' Bild-Lexikon der Anatomie. 9th ed. Stuttgart: Thieme; 2005.
15. Hamilton WJ, Boyd JD, editors. Textbook of human anatomy. London: MacMillan; 1956.
16. Platzer W, Putz R, Poisel S. Ein neues Konservierungs- und Aufbewahrungssystem für anatomisches Material. *Acta Anat [Basel]* 1978;102:60-7.
17. McHanwell S, Brenner E, Chirculescu ARM, Drukker J, van Mameren H, Mazzotti G, et al. The legal and ethical framework governing body donation in Europe – a review of current practice and recommendations for good practice. *Eur J Anat* 2008;12:1-24.
18. Harmon JV Jr, Edwards WD. Venous valves in subclavian and internal jugular veins. Frequency, position, and structure in 100 autopsy cases. *Am J Cardiovasc Pathol* 1987;1:51-4.
19. Franklin KJ. Valves in veins: an historical survey. *Proc R Soc Med* 1927;21:1-33.
20. Bleicher M, Weber P. De la repartition des valvules veinuses dans la saphen interne. *C R Assoc Anat* 1932;27:60-6.
21. Ogo M. On the venous valves of the Japanese. *Nihon Geka Hokan* 1933;10:541-91.
22. Nemoto I. Embryologic venous valves of Japanese – venous valve of the lower limbs. *Acta Anat Nipponica* 1943;21:170-89.
23. Shima H, Ohno K, Shimizu T, Michi K, Egawa K, Takiguchi R. Anatomical study of the valves of the superficial veins of the forearm. *J Craniomaxillofac Surg* 1992;20:305-9.
24. Jimura A, Nakamura Y, Itoh M. Anatomical study of distribution of valves of the cutaneous veins of adult's limbs. *Ann Anat* 2003;185:91-5.
25. Hamer JD, Malone PC, Silver IA. The PO₂ in venous valve pockets: its possible bearing on thrombogenesis. *Br J Surg* 1981;68:166-70.
26. Fisher J, Vaghaiwalla F, Tsitlik J, Levin H, Brinker J, Weisfeldt M, et al. Determinants and clinical significance of jugular venous valve competence. *Circulation* 1982;65:188.

Submitted May 3, 2011; accepted Jun 24, 2011.