Comparative Study of Morphology and Distribution of Valves in Human Retromandibular Vein

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Abstract

The objective of this study was to analyze the distribution and morphology of the valves in the human retromandibular vein. The retromandibular, internal thoracic, azygos, femoral, and brachial veins were harvested from 46 cadavers donated to the Department of Anatomy at Tokyo Dental College for dissection. The frequency of the valves in each vein, the length of the cusps, and the thickness of the vein itself were measured. Valves were present at high frequency (92.1%) in the veins of the limbs and had cusps at least twice as long as the internal diameter of the vein. Veins in the trunk contained a lower frequency of valves, with cusps that tended to be shorter (1.60 ± 0.77) than those of the venous valves in the limbs (2.12 ± 0.60). The valves of the retromandibular vein tended to resemble venous valves in the trunk in terms of both frequency and morphology. The main function of venous valves in the limbs is to prevent retrograde flow. Conversely, valves in the veins of the trunk and retromandibular vein play a role in retaining blood in the veins, and their relationship to other veins means that they can cause major hemorrhage.

Key words: Anatomical study—Venous valves—Retromandibular vein—Hemorrhage—Jaw surgery


**Introduction**

Veins are known to serve two functions: as conduits for blood returning to the heart; and as reservoirs for large volumes of blood, holding approximately 70% of the total blood volume in the body\(^5\). In veins in which valves are absent, blood is free to flow in either direction. Therefore, if such a vein sustains an injury, the resultant amount of blood flow will be vast\(^29\). Crick et al. suggested that differences in the cardiac and vascular morphologies in pigs, as representing quadrupeds, and in humans, as representing bipeds, were due to different orientations with respect to gravity\(^2\). The venous valves in human legs in the standing position play an important role in preventing gravity from causing retrograde blood flow away from the heart and reserving the blood within its various compartments. Iimura et al. focused on the structure of the valves within the veins, investigating their morphology and frequency in cutaneous veins\(^8\). In terms of venous valves in the maxillofacial region, Nishihara et al. and Zhang et al. reported a high frequency in the facial vein at the lower margin of the mandible\(^17,30\). Lin et al. found no venous valves between the pterygoid plexus and cavernous sinus, or in the ophthalmic, maxillary, or facial veins\(^5\). Reports of valves in the veins of the human head and neck remain extremely limited, however\(^15,22\). In particular, the retromandibular vein has no correspondingly named artery. Its morphology and environment are believed to differ from those of other veins, but many of its characteristics remain unclear.

In this study, retromandibular veins were harvested from human cadavers and their morphology and distribution analyzed to make a detailed comparative analysis with data on other major veins in the trunk and limbs. Structural differences between this vein and others in the head and neck, trunk, and limbs are also discussed in terms of the location, shape, and biomechanical role of their respective valves.

**Materials and Methods**

Samples were harvested from 46 sites in 46 cadavers donated to the Department of Anatomy at Tokyo Dental College for dissection (23 men, 23 women; mean age, 84.3 ± 9.8 years). The cadavers used in this study had been fixed in 10% formalin solution and preserved in 70% alcohol. The protocol of this study was approved by the Ethics Committee of Tokyo Dental College (Ethics Review No. 784). The retromandibular vein was harvested from the head and neck region, the internal thoracic and azygos veins from the trunk, and the brachial and femoral veins from the limbs\(^6\). Region of interest sites were as follows: the retromandibular vein was harvested from the point at which the superficial temporal vein and maxillary vein converge at the confluence with the facial vein\(^23\); the internal thoracic vein from the point at which the superior epigastric vein reaches the inferior thoracic aperture until reaching either the subclavian vein or brachiocephalic vein; the azygos vein from the height of the inferior margin of the 12th thoracic vertebra to the height of the 3rd thoracic vertebra; the brachial vein from the point at which the radial and ulnar veins converge at the inferior margin of the teres major muscle; and the femoral vein from the adductor hiatus to the inguinal ligament. Each vein was subsequently opened along its course and gross morphological observations conducted. The valves observed were measured directly with calipers (Miyutoyo Corporation, NTD12P-15C). Each measurement was made 3 times and the mean value calculated. Figure 1 shows the measurement parameters adopted. The internal diameter of the vein was calculated by measuring the width of the internal circumference at the inferior-most point of the valve and dividing this value by pi. The length of the valve relative to the internal diameter was also calculated and used as an index of valve shape.
Venous Valve of Retromandibular Vein

Results

Valves were present in 5 of the 40 retromandibular veins (12.5%) examined, compared to in only 4 of the 20 internal thoracic veins (20.0%) and 2 of the 20 azygos veins (10.0%), both of which are located in the trunk. However, the frequency of valves was much higher in the limb veins, with valves in 15 of the 18 brachial veins (83.3%) and in all of the femoral veins (100%) examined. Twelve of the 18 brachial veins (66.7%) examined had 2 or more valves, with 5 veins (27.8%) containing 3. Seventeen of the 20 femoral veins (85%) examined had 2 or more valves, and 10 (50%) contained 3 (Table 1). Of the 3 retromandibular veins showing valves, 2 were located at sites unrelated to a point of confluence, and 1 was located distal to the confluence of the retromandibular and facial veins (Fig. 2). In the azygos vein, the valves in many cases (5 of 20) were located at the terminus of the ascending lumbar vein, which is the radicular vein of the azygos vein. Valves in limb veins were mostly located distally to comparatively thick confluent veins. A total of 90 venous valves were observed in this study, including 1 in a femoral vein that was tricuspid and 2 in internal thoracic veins that had only 1 cusp each (Fig. 3).

All the 87 remaining valves were bicuspid. The cusps of all the venous valves examined were pointed toward the heart. The minimum ratio of valve length to internal venous diameter was 0.83, and the maximum was 3.77 (Table 2). Most of the valves in the limb veins were at least twice the length of the internal diameter of the vein, whereas the majority of the valves in the trunk veins were less than twice the length of the internal diameter (Table 3).

Discussion

The venous valve functions as a blood reservoir\(^2\). Veins are highly distensible, with compliance approximately 30 times that of arteries\(^2\). To enable veins to function efficiently as reservoirs, the pressure imposed on the blood within should always be controlled. In venous systems in which pumping is not reliant on the heart, valves act to compartmentalize blood inside the vessels in each area, thus pro-

![Fig. 1 Measurement site](image-url)

(a): Sites used for measuring length of valves, (b): Sites used for measuring diameter of valves

| Valve Type        | Retromandibular vein | Internal thoracic vein | Azygous vein | Brachial vein | Femoral vein |
|-------------------|----------------------|------------------------|--------------|---------------|--------------|
| non-valve         | 35/40 (87.5)         | 16/20 (80.0)           | 18/20 (90.0) | 3/18 (16.7)   | 0/20 (0.0)   |
| 1 valve           | 5/40 (12.5)          | 4/20 (20.0)            | 2/20 (10.0)  | 3/18 (16.7)   | 3/20 (15.0)  |
| 2 valves          |                      |                        | 7/18 (38.9)  | 7/20 (35.0)   |              |
| 3 valves          |                      |                        | 5/18 (27.8)  | 10/20 (50.0)  |              |

Number (%)
viding an extremely efficient means of controlling blood pressure. For this reason, valves are very densely distributed in the veins of both the arms and the legs. In this study, all the femoral veins and almost all the brachial veins examined contained valves, a finding generally consistent with the observations of Moore et al. On the other hand, the facial vein is a superficial vessel, as are the femoral and brachial veins, and its valves can be regarded as mainly functioning to prevent retrograde flow. In the trunk, on the other hand, the frequency of venous valves is low, appearing in only 10% to 20% of internal thoracic and azygos veins examined in this study. This may be because these veins are located near the heart, close to the superior vena cava and other large veins. The volume of blood ejected in a single heartbeat is almost exactly the amount collected in the right atrium from the superior and inferior vena cava. The blood contained in veins near the heart is thus almost all collected in the heart at once, suggesting that there is no need for venous valves at locations other than where blood is particularly likely to collect. In the head and

Fig. 2 Valve of retromandibular vein
(a): Related valve in facial vein, (b): Unrelated valve in facial vein
FV: Facial vein, IJV: Inter-jugular vein, MXV: Maxillary vein, STV: Superficial temporal vein.

Fig. 3 (a): Three cusps in femoral vein, (b): One cusp in internal thoracic vein #1, (c): One cusp in internal thoracic vein #2
### Table 2  Measurement values of all valves

| Retromandibular vein | Internal thoracic vein | Azygous vein | Brachial vein | Femoral vein |
|----------------------|------------------------|--------------|--------------|--------------|
| Diameter | Length | Index | Diameter | Length | Index | Diameter | Length | Index | Diameter | Length | Index |
| 3.56 | 11.37 | 3.20 | 3.26 | 6.00 | 1.84 | 8.60 | 7.17 | 0.83 | 6.36 | 6.60 | 1.04 | 6.61 | 10.37 | 1.57 |
| 5.62 | 5.50 | 0.98 | *2.63 | 2.57 | 0.97 | 3.86 | 4.53 | 1.17 | 6.53 | 11.43 | 1.75 | 5.84 | 12.00 | 2.06 |
| 3.97 | 4.17 | 1.05 | 3.38 | 6.70 | 1.98 | 5.30 | 8.33 | 1.57 | 5.98 | 16.17 | 2.70 | |
| 3.21 | 4.98 | 1.55 | *3.01 | 7.40 | 2.45 | 5.88 | 7.13 | 1.21 | 5.52 | 16.57 | 3.00 | |
| 3.47 | 4.55 | 1.31 | |

4.07 | 7.23 | 1.78 | 7.32 | 13.73 | 1.87 | 5.34 | 8.73 | 1.64 | 7.06 | 19.33 | 2.74 |

5.34 | 6.17 | 1.15 | 4.90 | 14.33 | 2.92 | 3.90 | 6.27 | 1.61 | 4.28 | 12.30 | 2.88 |

3.83 | 6.40 | 1.67 | 5.55 | 13.53 | 2.44 | 4.52 | 10.07 | 2.23 | 7.14 | 14.47 | 2.02 |

4.48 | 12.87 | 2.87 | 7.04 | 18.67 | 2.65 | 4.73 | 6.53 | 1.38 | 6.49 | 11.70 | 1.80 |

3.38 | 7.80 | 2.31 | 6.42 | 9.30 | 1.45 | 2.90 | 5.23 | 1.81 | 4.60 | 12.90 | 2.81 |

2.75 | 7.13 | 2.59 | 4.70 | 13.93 | 2.96 | 2.36 | 6.20 | 2.63 | 5.81 | 13.37 | 2.30 |

1.79 | 6.03 | 3.36 | 6.45 | 13.47 | 2.09 | 6.32 | 11.57 | 1.83 | 5.55 | 8.90 | 1.60 |

5.54 | 6.83 | 1.23 | 5.87 | 14.60 | 2.49 | 5.80 | 9.13 | 1.58 | 5.35 | 19.93 | 3.73 |

4.46 | 11.57 | 2.59 | 4.82 | 9.20 | 1.91 | 4.70 | 9.30 | 1.98 | 4.45 | 9.20 | 2.07 |

4.33 | 7.53 | 1.74 | 4.60 | 13.03 | 2.84 | 2.69 | 5.17 | 1.92 | 8.06 | 15.07 | 1.87 |

4.35 | 8.17 | 1.88 | 6.55 | 24.67 | 3.77 |

3.09 | 6.90 | 2.23 | 7.43 | 13.00 | 1.75 | 5.86 | 9.10 | 1.55 | 7.92 | 14.57 | 1.84 |

5.37 | 8.33 | 1.55 | 4.52 | 10.10 | 2.23 | 3.97 | 5.27 | 1.33 | 3.61 | 7.13 | 1.98 |

2.56 | 4.10 | 1.60 | 4.56 | 8.17 | 1.79 | 3.90 | 11.87 | 3.05 | 3.42 | 8.77 | 2.56 |

4.71 | 12.73 | 2.70 |

7.70 | 17.53 | 2.28 |

7.72 | 16.07 | 2.08 |

7.74 | 16.47 | 2.13 |

3.64 | 8.07 | 2.22 |

5.04 | 14.27 | 2.83 |

5.54 | 10.73 | 1.94 |

4.28 | 8.57 | 2.00 |

4.88 | 8.40 | 1.72 |

*6.09 | 8.87 | 1.46 |

*: one cusp

#: three cusp

(Diameter: mm, Length mm)
neck region, blood that has collected in the cavernous sinus, pterygoid plexus, and other reticulate veins then travels from the maxillary vein via the retromandibular vein into the internal jugular vein from behind the mandibular ramus. The valves in the retromandibular vein, which is not a superficial vessel, function more to compartmentalize the vein than prevent retrograde flow. It is possible that the resulting amelioration of perfusion of the internal jugular vein is why the former has fewer valves.

Nishihara et al. showed that around 30% of valves in the facial vein have cusps twice the length of the internal venous diameter. The valves of the limb veins also had cusps that were more than twice the length of the internal diameter of the vein. This is because longer cusps offer better closure of veins than shorter cusps. However, the length of the valves in the trunk, including those in the retromandibular vein, tends to be shorter than that of those in the limbs. The retromandibular vein is defined as running from the convergence of the maxillary vein and superficial temporal vein that enters the facial vein on the posterior side of the angle of the mandible. This vein runs very close to the posterior border of the mandibular ramus and is therefore vulnerable to damage during perimandibular surgery. Valecchi reported that although valves were present in 88% of internal jugular veins, retrograde flow occurred in 90% of such cases. This suggests that major hemorrhage from the retromandibular vein is due to retrograde flow from the internal jugular vein, which is close to the heart and has high internal pressure.

Advances in therapeutic technologies and surgical instruments mean that orthognathic surgery has become a standard oral surgical procedure that is now widely performed. One such operation, mandibuloplasty, is almost always carried out by either sagittal split ramus osteotomy or intraoral vertical ramus osteotomy. Some of the sequelae of these procedures, which include major hemorrhage, sensory disturbance in the lower lip, and abnormal fracture, demand that caution be taken when they are performed. Major hemorrhage occurring at an unexpected location or time, in particular, can be life-threatening. A few cases of unexpected hemorrhage around the mandible during mandibuloplasty have been reported. Teltzrow et al. described a case of major hemorrhage due to damage to the retromandibular vein during orthognathic surgery. They stated that the amount of hemorrhage was much greater than would normally be expected from venous hemorrhage and suggested that the risk of damage is greater when the retromandibular vein is adjacent to the posterior margin of the mandibular ramus. According to Oh et al., hemorrhage resulting from damage to these veins may reach as much as 8.5 liters. The present study found that the retromandibular vein, which plays an important role as a blood reservoir, contained few venous valves. The frequency of the valves in the retromandibular vein was close to that observed in the veins in the trunk. This suggests that this vein collects blood returning to the heart from deep veins such as the pterygoid plexus.

Table 3 Index of valve shape

| Valve Type          | Trunk            | Limb             |
|---------------------|------------------|------------------|
| Retromandibular vein| 1.62 ± 0.91      | 2.12 ± 0.60      |
| Internal thoracic vein| 1.81 ± 0.62      | 1.60 ± 0.77      |
| Azygous vein        | 1.00 ± 0.24      | 2.31 ± 0.56      |
| Brachial vein       | 1.85 ± 0.54      |                  |
| Femoral vein        | 2.31 ± 0.56      |                  |

Mean (mm)
and maxillary vein, functioning as a reservoir for blood collection in the head and neck region. This indicates that understanding the course and location of important vessels susceptible to damage prior to commencement of surgery, deciding on the approach to be therefore taken, and putting measures in place to deal with possible intraoperative hemorrhage is crucial, especially in the oral and maxillofacial region.\textsuperscript{3,12,21}

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