The ovine jugular vein as a model for interventional radiology procedures

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Background. *Detailed knowledge of the ovine jugular vein anatomy and physiology is a prerequisite for proper use of sheep as teaching or an experimental model in interventional radiology.*

Material and methods. *Ascending and descending jugular venograms in tilted position were done in 25 sheep to evaluate the jugular vein (JV) size and anatomy of its valves.*

Results. *The average maximal diameter of 50 JVs was 13.34 ± 1.18 mm. Each vein contained an average of 4.36 ± 0.98 valves. All valves were competent and 96.3% were bicuspid.*

Conclusions. *Because of similarities between ovine JV and human femoral vein in regards to diameters, number and type of valves and function of their valves with increased central and hydrostatic pressure, the ovine JV is a good model for evaluation of creation of JV valve incompetence, percutaneous valve transplantation and evaluation of prosthetic valve devices.*

Key words: jugular vein; experimental model, ovine; interventional radiology

Introduction

Percutaneous techniques have emerged as minimally invasive options in the treatment of chronic venous insufficiency. For replacement of diseased or absent venous valves,

several artificial percutaneously implanted valves have been developed over the last 10 years.[1-5] The ovine jugular vein (JV) has been often used for testing of the new valve devices because of its similar size to human femoral vein.[3,5-10] However, to our knowledge, there has not been a detailed study on the ovine JV angiographic anatomy, particularly regarding the number, distribution and type of its valves. The purpose of this study is to describe the angiographic anatomy of the ovine JV and its valves as a suitable model for interventional radiology procedures.

Materials and methods

The study involved 25 adult female sheep weighing 53-74 kg (mean 64 kg) and was a part of the following studies: testing a new bioprosthetic valve testing (7 sheep), attempts of creation of primary venous insufficiency (8 sheep) and testing new IVC filters (10 sheep). The Institutional Animal Care and Use Committee of Oregon Health & Science University approved the protocols of these studies.

Animals fasted overnight with water available and were tranquilized intravenously with 7.5-10 mg (0.05 mg/lb) of Diazepam (Midazolam; Ben Venue Labs, Bedford, OH) and 400-800 mg (2.0 mg/lb) of Ketamine (Ketaset; Ft. Dodge Animal Health, Ft. Dodge, IA). Animals were then intubated. Inhalation anesthesia was maintained with 2-2.5% Isoflurane (IsoFlo; Abbott Laboratories, Chicago, IL) and 2 L/min of oxygen. To reduce salivation, 5 mg Atropine sulfate (American Regent Laboratories, Shirley, NY) was administered intravenously. Antibiotics (10 mg/kg cefazolin) were given intramuscularly as single dose at the beginning of procedures. Respiratory rhythm and carbon dioxide saturation were monitored during procedure. A GE/OEC 9800 cardiac mobile system with digital imaging (GE Medical Systems/OEC, Salt Lake City, UT) was used for imaging.

Both JVs were percutaneously entered just below the jaw and 7 cm long 6.0 FR Check-Flo vascular sheaths (Cook Medical, Bloomington, IN) were introduced and used to obtain venograms. A graduate measuring 0.035-inch wire guide (Cook Medical) was introduced into each sheath for calibration during venography. The right femoral vein was percutaneously entered and a 110 cm long 5 F H1 Torcon Advantage catheter (Cook Medical) was introduced and advanced into the JV below its most central valve for descending venograms. Both ascending and descending venograms were performed with the sheep in approximately 30 degrees tilted position (head down) using hand injections of 10-20 ml of contrast medium. Filming of each vein was performed in two projections and was prolonged to visualize the residual contrast in the valvular cusps. Simultaneous venograms of both JVs were also performed in anterio-posterior projection for visualization their anatomical relation. In 10 animals evaluated for IVC filters placement, the descending venograms of each JV valve were performed after the H1 catheter was passed through the competent central valves.

After venographic study of the JV anatomy, the animals underwent further testing according to the protocols. Four animals were terminated immediately after these studies and specimens of their JVs were obtained for comparison with their venograms. The other 21 animals were used for long-term evaluation.

The diameters of JVs were measured on the venograms and the number of venous valves, the type of valves (number of their cusps), and their distribution were carefully studied. The JVs were divided into thirds, the peripheral (distal), the middle and the central (proximal) segments.

Results

On the tilted ascending venograms, the JVs were well filled, distended and circular in shape. Their filling extended peripherally above the access site to the most peripheral competent valve. Some venous tributaries were also filled to their first venous valve. The JV diameters ranged from 9.8 mm to 15.2 mm with an average of 13.34±1.18 mm. The JV diameters in the peripheral segment ranged from 12.5 mm to 15.2 mm with an average of 14.28±1.06 mm. In the middle segment vein diameters ranged

Table 1. Jugular vein diameters, valve distribution and frequency

Segments	Diameter (mm)	Valve Distribution	Valve Frequency
Peripheral	14.28±1.06	58 (26.6%)	92%
Middle	12.68±1.14	41 (18.8%)	76%
Central	12.92±1.03	119 (54.6%)	100%

from 10.6 mm to 13.7 mm with an average of 12.68±1.14 mm. The JV diameters in the central third ranged from 9.8 mm to 13.2 mm with an average of 12.92±1.03 mm (Table 1). The distended venograms often displayed the venous valves as faint linear defects inside sinuses, extending from the wall into lumen (Figure 1b). In the later phase of venograms valves were better visualized as their cusps contained some residual of contrast material and it was possible to define the number of cusps as well (Figures 1a, 1c). Altogether 218 valves were found in 50 JVs, with a range from 3-7 (4.36±0.98) valves in each JV. Most valves (210) were bicuspid (96.3%). Five valves had one cusp (monocusp – 2.3%) and three had three cusps (tricuspid – 1.4%). The major-

ity of valves 119 (54.6%) were distributed in the central venous segment that always contained at least two valves. In the middle segment, there were 41 (18.8%) valves with 3 JVs containing two valves. Twelve middle segments were without valves. In the peripheral segment, there were 58 (26.6%) valves. Four JVs peripheral segments were without valves.

The descending venograms displayed the valves and their types, whether they had one, two or three cusps well (Figure 2). The valves were competent and the hand injections filled the venous branches central to the valve. The axillary veins were always filled during injection below the central positioned valves. A perforating vein between the jugular and vertebral vein was filled
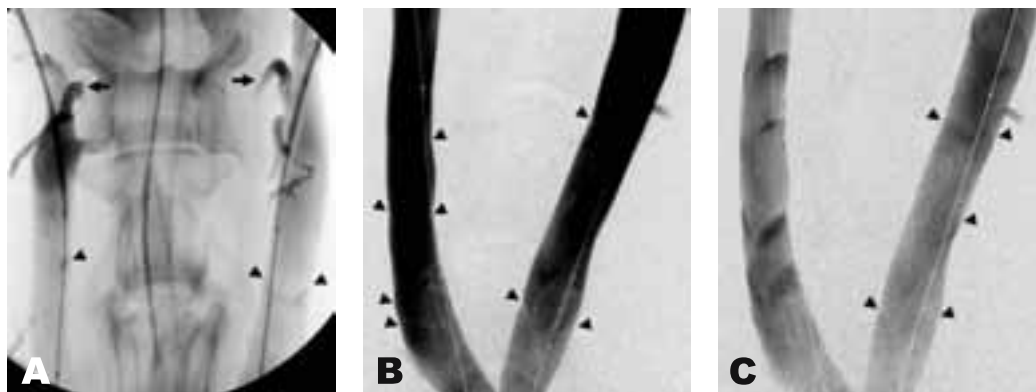
Figure 1 a-c. Ascending venograms of the jugular veins done in a titled position.
(a) Late phase venogram of the peripheral segment of the jugular vein demonstrates a monocusp valve on the right side (arrowhead) and bicuspid valve on the left side (arrowheads). There is filling of jugular vein tributaries and perforators vein (arrows).
(b) Early phase subtraction venograms of the middle and central segments of the jugular veins demonstrate valves as linear defects inside the vessel filled venous sinuses.
(c) Late phase subtraction venogram of the middle and central segments of the jugular veins demonstrates valves as residual filling in the valve cusps. Five bicuspid valves are seen on the right side and three on the left side (arrowheads).
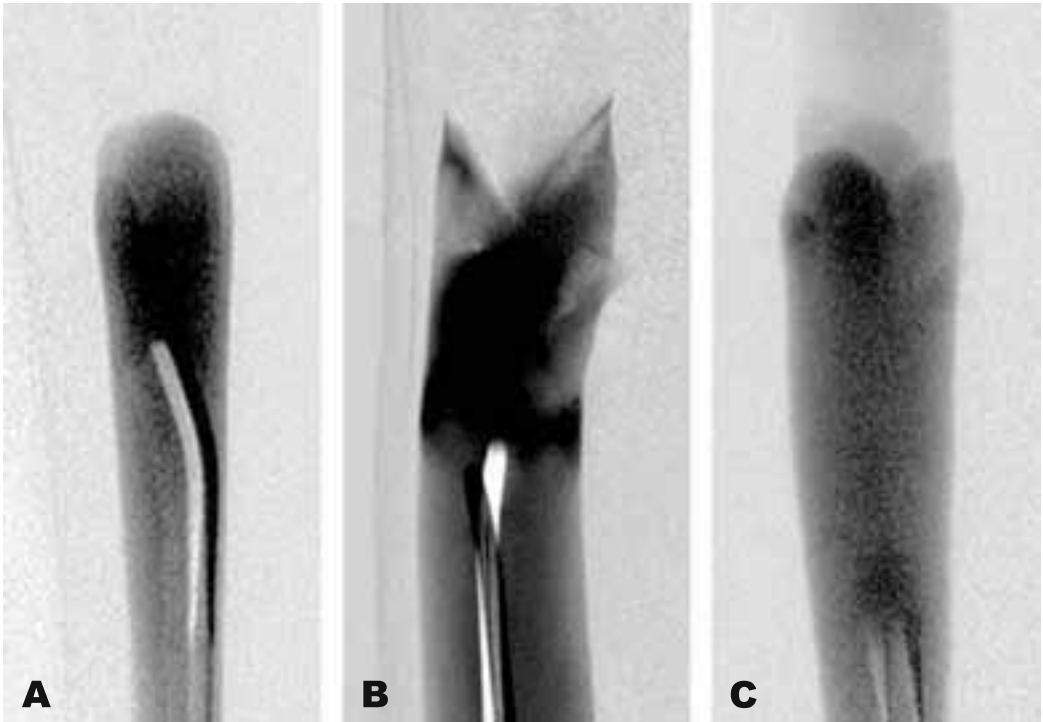
Figure 2 a-c. Descending venograms done in tilted position with injections central to valves demonstrate three types of valves. **(a)** Monocusp valve **(b)** Bicusps Valve **(c)** Tricusps valve.

when injection occurred below the most peripheral valve.

The specimens of 8 JVs removed at the autopsies in four animals showed the same number, distribution and type of valves. All were bicuspid as seen on their venograms (Figure 3).

Discussion

Detailed knowledge of the ovine jugular vein anatomy and physiology is a prerequisite for proper use of sheep as teaching or an experimental model in interventional radiology. The ovine JV, also called the external JV, is the largest vein in the neck and drains most blood from the head and neck. The internal JV in sheep is small and often absent.[11] The JV originates near the ventral border of the parotid gland at the angle of the mandible by the union of the external and internal maxillary veins. Traversing in the neck in the muscle groove, the JV accepts small tributary veins from thyroid, trachea, esophagus and muscles. Two axillary veins join the JV in its central segment at its entrance into the thorax.[11] The right and left JVs then unite to form the superior vena cava. The JVs are thin-walled vessels and at surgery were found to have a mean diameter of approximately 9 mm.[8] During ascending venography in tilted position, the JVs distend and their mean diameter was 13.34±1.18 in the presented series. The measurement of the maximal JV diameter during distention is important for selection of proper size of the valvular devices that we were testing. To prevent migration,
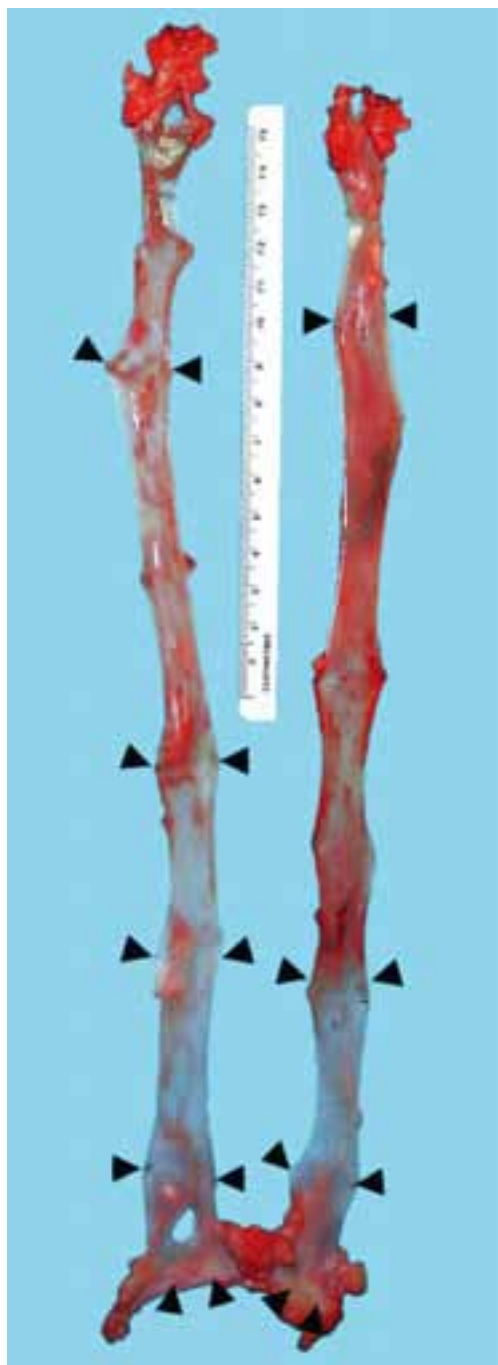
Figure 3. Longitudinally cut open specimen of both jugular veins 26 cm in length shows 5 bicuspid valves (arrow heads) on the right and four bicuspid valves on the left side (arrowheads).

Figure 4. A pentacusps valve. Venoscopy shows five well functioning cusps.

the device should have a diameter about 15 to 20% larger than the vein diameter.[3]

The valves in veins are located peripherally to the entrance of large venous tributaries or junction of two veins of equal diameter.[12] The valves close during increased central or hydrostatic pressure and prevent blood reflux and venous hypertension peripherally. Ascending venography demonstrated that the ovine JV contains one valve constant at its origin and two constant valves in its central segment at the entrance of two axillary veins. The number of valves in the middle segment was variable and ranged from zero to two. Venographic documentation of the presence and number of valves in the JV that compared well with the specimen studies is more accurate than their surgical identification. With valve identification by white semi-lunar lines formed by the attachment of the valve cusp to the vein wall, Jessup and Lane found only one to three valves in the jugular vein and in 3 of 32 veins (9.4%) found no valves.[8] The JV valves are mostly bicuspid, 96.3% in our series. JV valves are rarely monocuspid or tricuspid type. We found 2.3% and 1.4%, respectively in our se-

ries. However, valves with more than three cusps can also occur. In our previous experience with venoscopy of JV specimens, we found a (quintacusp) valve containing 5 well functioning cusps (Figure 4). In our series all JV valves evaluated by venography exhibited good function. All were competent and no venous reflux was seen during descending venography in tilted position. We consider venographic evaluation of valve competency more physiologic and accurate than the milking technique used by surgeons during open surgery. Using this technique, Jessup and Lane found that 18 of 32 JVs (56.3%) in normal sheep had partially or completely incompetent valves.[8]

The ovine JV is a good model for evaluation of new percutaneously placed venous devices because of its similarities with the human femoral vein (FV).[3] These similarities include their diameters, number, and type of valves and function of their valves with increased central and hydrostatic pressures. The diameter of the ovine JV is around 13.34 mm in the tilted position and compares well with the diameter of the normal standing human FV of 10.0±0.21 mm.[13] The number and distribution of valves are also similar. The ovine JV contains a mean of 4.6 valves in a vein length of about 25 cm to 30 cm. The human FV contains an average of 5 valves from the knee to the inguinal ligament including the constant valves at its central and peripheral end.[14] Most of the valves in the ovine JV and the human FV are of bicuspid type and function similarly. They are open during relaxation and with muscle contraction. An increased central venous pressure causes the competent valves to close and prevent venous reflux and peripheral venous hypertension. In humans, the competent FV valves close with increase hydrostatic pressure in the upright position, and episodically pressure increases during deep breathing, straining and coughing. The function of JV valves in quadrupeds is to maintain the direction of the blood flow toward the heart and to protect the capillary beds of the head from the high venous pressure pulses caused by chest compressions and during eating and drinking with their heads down.[15]

Venographic studies are essential for both the evaluation of JV anatomy prior to prosthetic valve device placement and for following-up their function. Ascending venograms in the tilted position gives information about the JV size and position of their valves, particularly the central valve. As mentioned above, a prosthetic valve should be 15 to 20% larger than the JV diameter. The experimental prosthetic valves have been always placed across the central valve to replace its function.[3,7,9] Because placement of one prosthetic valve will probably not solve chronic venous insufficiency, placement of two or more prosthetic valves will need to be evaluated in the ovine JV. Therefore, determination of position of other JV valves will be necessary. Descending venography can be done as a part of the preplacement evaluation, particularly if there is a question regarding the type and competency of the central valve. For follow-up studies, however, descending venography is the main procedure to evaluate valve competency.[16,17] Ascending venography must also be done at that time to visualize the entire JV and evaluate any changes related to the prosthetic valve placement.

Acknowledgements

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