Duplex ultrasonography of the common carotid artery and external jugular vein of cows

Ueli Braun, Prof Dr med vet, and Josef Föhn, Dr med vet

Objective—To determine blood flow patterns in the common carotid artery and external jugular vein in cows before and after sedation achieved by administration of xylazine hydrochloride.

Animals—30 clinically normal Swiss Braunvieh cows.

Procedure—A 5.0-MHz sector transducer was used to examine the common carotid artery and external jugular vein before and after cows were sedated by administration of xylazine. Several variables were calculated, including diameter of the blood vessels, blood flow velocity, and flow-time volume.

Results—The common carotid artery before sedation had a maximum systolic velocity of 89 ± 8.5 cm/s, maximum diastolic velocity of 36 ± 6.0 cm/s, mean velocity of 35 ± 5.4 cm/s, and flow-time volume of 28.2 ± 3.48 cm^3/s. In all cows, sedation achieved by administration of xylazine resulted in a significant decrease in velocity of arterial blood flow and flow-time volume. The external jugular vein before sedation had a maximum velocity of 65 ± 8.3 cm/s, maximum velocity of retrograde venous blood flow of 20 ± 6.6 cm/s, and flow-time volume of 29.7 ± 5.42 cm^3/s. These values decreased significantly after cows were sedated by administration of xylazine.

Conclusions and Clinical Relevance—Doppler ultrasonography is particularly suitable for evaluation of blood flow patterns in the common carotid artery and external jugular vein of healthy cows. The results reported here provide a basis for use in examination of cows with cardiac and blood vessel disease. (*Am J Vet Res* 2005;66:962–965)

Duplex ultrasonography, which combines B-mode and Doppler ultrasonography, is a straightforward and noninvasive method for examination of blood vessels.[1] Clear observation of morphologic characteristics of vessels can be achieved with B-mode ultrasonography, whereas Doppler ultrasonography allows evaluation of blood flow patterns within specific regions of vessels. Changes in blood flow patterns within arteries and veins of the neck are evident for several diseases in humans. The most important are arteriosclerosis and venous thrombosis.[1] Doppler ultrasonography can be used to identify changes in blood flow patterns indicative of disease of the arterial wall before these lesions can be seen on B-mode ultrasonograms. Doppler tracings of the arteries of the neck in humans have been established for some time. A peripherally directed, monophasic, systolic-diastolic blood flow pattern is typical of the common carotid artery in clinically normal humans.[1] An early diastolic retrograde flow of blood toward the heart, which is seen in arteries with high peripheral resistance, is not typically seen in the common carotid artery. Pulsed-wave Doppler ultrasonography of the common carotid artery has been described in horses.[2,3] In those studies, blood flow patterns were evaluated in standing nonsedated horses[2,3] as well as in horses that were sedated or anesthetized.[3]

Determination of compressibility, filling, and respiration-dependent movement of the vessel wall are the most important aspects of clinical examination of the jugular vein in humans.[4] Uninterrupted venous blood flow is hemodynamically modulated by respiration and characterized by a lack of appreciable retrograde flow peripherally. Within the venous blood system, respiratory effects on blood flow become increasingly overshadowed by effects of cardiac activity close to the right atrium. There are 2 flow peaks (1 associated with the early diastolic filling phase and the other with the suction of blood from the veins into the atria as a result of the movement of the closed atrioventricular valves toward the cardiac apex during ventricular ejection). This bifid peak is followed by a decrease in blood flow during atrial contraction and ventricular relaxation.[4]

In cattle, the external jugular vein and common carotid artery can be examined ultrasonographically.[5,a] However, to our knowledge, there are no published reports about Doppler ultrasonography of these vessels in healthy cattle. Cardiac diseases such as endocarditis and cardiomyopathy, compression of vessels near the heart by space-occupying lesions, and obstruction of vessels by thrombi are often difficult to diagnose clinically. It would be advantageous to obtain information about the ultrasonographic blood flow patterns in these disorders to aid in their diagnosis. For example, abnormal blood flow in the common carotid artery has been recorded by use of duplex ultrasonography in a cow with idiopathic cardiomyopathy and in the external jugular vein in another cow with endocarditis of the tricuspid valve.[a] The goal of the study reported here was to use pulsed-wave Doppler ultrasonography to evaluate blood flow in the external jugular vein and common carotid artery of clinically normal cattle to establish reference ranges that may aid clinicians in the diagnosis of diseases affecting these major vessels.

Materials and Methods

Animals—Thirty clinically normal Swiss Braunvieh cows were used in the study. Cows were between 2.9 and 9.0 years of age (mean ± SD, 3.6 ± 1.3 years) and weighed between 469 and 632 kg (mean, 532 ± 44 kg).

Procedure—Food was withheld from all cows for 12 hours prior to ultrasonographic examination. The skin over

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From the Department of Farm Animals, Veterinary Faculty, University of Zurich, Winterthurerstrasse 260, CH-8057 Zurich, Switzerland.
Address correspondence to Dr. Braun.

the right jugular furrow was clipped, and any remaining hair was removed by use of a depilatory cream. The head of each cow was tied to a post during ultrasonography. The head was immobilized at a height of 90 cm above the ground.

Vessels on the right side of the cows were examined by use of a 5.0-MHz sector transducer and real-time scanner with a built-in pulsed-wave Doppler function.[b] The incident angle was 46° but sometimes had to be corrected to a maximum of 56°. Gain of the B-mode display was set at a depth of 6 cm. Size of the Doppler window was chosen to accommodate the diameter of the blood vessel. We muted the sound (ie, volume) for the acoustic Doppler signal because it disturbed the cows. Three successive measurements were performed, and the mean was calculated. Each cow was then administered xylazine hydrochloride[c] (0.03 mg/kg) in the left jugular vein. Ultrasonography was repeated 10 minutes after administration of xylazine.

Flow variables for the common carotid artery—The right common carotid artery of each cow was viewed in longitudinal section to evaluate blood flow variables.[5,a] The Doppler beam with a corrected incident angle was directed into the vessel lumen within the Doppler window by use of the transducer held parallel to the vessel wall. The B-mode image was frozen on 1 ultrasound screen, and the Doppler function was then activated so that the Doppler signal was visible on a second screen. Variables of the cardiac cycle were automatically determined by software of the ultrasound machine, including maximum velocity of systolic blood flow, maximum velocity of diastolic blood flow, maximum velocity of retrograde blood flow, mean velocity of arterial blood flow, duration of systole, duration of diastole, duration of retrograde blood flow, difference between velocities of systolic and end-diastolic blood flow, and duration of systolic acceleration. Diameter and wall thickness of the common carotid artery and the distance between the Doppler measurement point and skin surface were measured by use of electronic cursors on the ultrasound machine. The ultrasound machine used the aforementioned variables to calculate arterial flow-time volume and systolic acceleration.

Flow variables for the external jugular vein—The right external jugular vein of each cow was viewed in longitudinal section at a location immediately cranial to the cranial vena cava.[5,a] Care was taken to avoid compression of the vein during scanning. Diameter of the external jugular vein was determined by use of electronic cursors on the ultrasound machine. The Doppler window was held parallel to the vessel wall, and the Doppler beam with a corrected incident angle was directed into the vessel lumen. The Doppler signal was recorded for 8 seconds, during which time several variables were determined, including maximum velocity of venous blood flow, maximum velocity of retrograde blood flow, mean velocity of retrograde blood flow, mean velocity of venous blood flow, and venous flow-time volume.

Statistical analysis—Statistical analysis was performed by use of a statistics program.[d] The mean, SD, and frequency distribution were determined for all variables. Values measured before and after sedation for each variable were compared by use of an ANOVA and a *t* test.

Results

Common carotid artery—The region for Doppler determinations was (mean ± SD) 3.4 ± 0.78 cm from the skin surface. Before sedation, maximum velocity of systolic blood flow was 89.0 ± 8.5 cm/s, maximum velocity of diastolic blood flow velocity was 36.0 ± 6.0 cm/s, and mean velocity of arterial blood flow was 35.0 ± 5.4 cm/s (**Table 1**). After sedation, there was a decrease of 18% in maximum velocity of systolic blood flow (73.0 ± 9.1 cm/s), a decrease of 20% in maximum velocity of diastolic blood flow (29.0 ± 4.6 cm/s), and a decrease of 40% in mean velocity of arterial blood flow (20.0 ± 3.2 cm/s). The duration of systole was not affected by sedation (0.39 ± 0.02 seconds before sedation and 0.38 ± 0.04 seconds after sedation). In contrast, the duration of diastole increased from 0.62 ± 0.11 seconds before sedation to 0.93 ± 0.12 seconds after sedation. This increase accounted for a decrease in heart rate (60.0 ± 7.1 beats/min before sedation to 46 ± 5.4 beats/min after sedation). Maximum velocity of retrograde blood flow increased from a mean of 8.0 ± 5.8 cm/s before sedation to 15.0 ± 9.1 cm/s after sedation, and the duration of retrograde blood flow increased from 0.05 ± 0.04 seconds before sedation to 0.10 ± 0.05 seconds after sedation. Systolic acceleration decreased from 601 ± 82.2 cm/s^2 before sedation to 511 ± 71.2 cm/s^2 after sedation.

Table 1—Mean ± SD (reference range) values for duplex ultrasonography of the right common carotid artery in 30 cows before and after sedation achieved by the administration of xylazine hydrochloride.

Variable	Before sedation	After sedation
Maximum velocity of systolic blood flow (cm/s)	89 ± 8.5 (73–107)	73 ± 9.1* (55–91)
Maximum velocity of diastolic blood flow (cm/s)	36 ± 6.0 (24–49)	29 ± 4.6* (20–38)
Maximum velocity of retrograde blood flow (cm/s)	8 (0,19)†	15 (0, 32)†
Mean velocity of arterial blood flow (cm/s)	35 ± 5.4 (24–45)	20 ± 3.2* (14–27)
Duration of systole (s)	0.39 ± 0.02 (0.35–0.44)	0.38 ± 0.04 (0.31–0.45)
Duration of diastole (s)	0.62 ± 0.11 (0.41–0.83)	0.93 ± 0.12* (0.70–1.16)
Duration of retrograde blood flow (s)	0.05 (0, 0.11)†	0.10 (0, 0.17)†
Difference between velocities of systolic and end-diastolic blood flow (cm/s)	70 ± 12.7 (44–95)	60 ± 9.6* (41–79)
Duration of systolic acceleration (s)	0.12 ± 0.01 (0.10–0.14)	0.12 ± 0.01 (0.10–0.14)
Diameter of common carotid artery (cm)	1.02 ± 0.08 (0.8–1.1)	1.10 ± 0.10* (1.0–1.3)
Wall thickness of common carotid artery (mm)	1.4 ± 0.16 (1.1–1.7)	1.3 ± 0.18 (1.0–1.7)
Arterial flow-time volume (cm^3/s)	28.2 ± 3.48 (21.2–35.2)	19.1 ± 2.04* (14.7–23.6)
Systolic acceleration (cm/s^2)	601 ± 82.2 (437–766)	511 ± 71.2* (369–654)
Heart rate (beats/min)	60 ± 7.1 (46–74)	46 ± 5.4* (35–57)

Reference range was calculated as the mean ± 2 SD.

*Within a variable, the value differs significantly ($P = 0.01$) from the value before sedation. †Values reported are mean (minimum, maximum) because the values were not normally distributed.

Table 2—Mean ± SD (reference range) values for duplex ultrasonography of the right external jugular vein in 30 cows before and after sedation achieved by the administration of xylazine hydrochloride.

Variable	Before sedation	After sedation
Maximum velocity of venous blood flow (cm/s)	65 ± 8.3 (48–82)	41 ± 9.4* (22–59)
Maximum velocity of retrograde venous blood flow (cm/s)	20 ± 6.6 (6–33)	15 ± 7.1 (1–29)
Mean velocity of venous blood flow (cm/s)	16 ± 3.4 (9–23)	8 ± 2.0* (4–12)
Mean velocity of retrograde venous blood flow (cm/s)	3 (1, 5)†	2 (1, 4)†
Diameter of external jugular vein (cm)	1.55 ± 0.15 (1.26–1.84)	1.90 ± 0.19* (1.47–2.36)
Venous flow-time volume (cm^3/s)	29.7 ± 5.42 (18.8–40.6)	21.6 ± 4.19* (13.2–29.9)

See Table 1 for key.

Sedation achieved by administration of xylazine resulted in an increase in the diameter of the carotid artery (1.02 ± 0.08 cm and 1.10 ± 0.10 cm before and after sedation, respectively). Despite this, the arterial flow-time volume decreased from 28.2 ± 3.48 cm^3/s before sedation to 19.1 ± 2.04 cm^3/s after sedation.

External jugular vein—In all cows, sedation achieved by administration of xylazine resulted in decreased blood flow, as evidenced by a decrease in the velocity spectrum and a significant decrease in blood flow velocity. Maximum velocity of venous blood flow decreased from 65.0 ± 8.3 cm/s before sedation to 41.0 ± 9.4 cm/s after sedation (**Table 2**). Maximum velocity of retrograde venous blood flow also decreased from 20.0 ± 6.6 cm/s before sedation to 15.0 ± 7.1 cm/s after sedation. Mean velocity of venous blood flow decreased from 16.0 ± 3.4 cm/s before sedation to 8.0 ± 2.0 cm/s after sedation. In contrast, the diameter of the external jugular vein increased from 1.55 ± 0.15 cm before sedation to 1.90 ± 0.19 cm after sedation. Despite this, venous flow-time volume decreased from 29.7 ± 5.42 cm^3/s before sedation to 21.6 ± 4.19 cm^3/s after sedation.

Discussion

As expected, xylazine had a marked effect on cardiovascular function in terms of flow variables and morphologic characteristics of the carotid Doppler tracing. It caused a decrease of 20% to 40% in blood flow velocities and flow-time volume. However, it is important to mention that errors in quantitative flow measurements may have resulted because of the effects of pulsatile flow, turbulence, and incorrect measurements of vessel diameter.[e] Xylazine-induced sedation in standing calves resulted in a decrease in cardiac output by 15% to 25%,[6] and in healthy cows, a dosage of 0.01 mg/kg (one third the dosage used in the study reported here) caused the heart rate to decrease from 60 to 52 beats/min.[f] In 1 study,[7] administration of xylazine (0.15 mg/kg, IM) resulted in a decrease in heart rate in healthy cows and cows with bovine spongiform encephalopathy and a decrease in systolic blood pressure in the healthy cows.

In contrast to results reported for goats,[8] we detected a significant decrease in the maximum velocity of systolic blood flow in the common carotid artery after xylazine-induced sedation and a decrease in the maximum velocities of diastolic and mean blood flow. Our results support those of other authors,[6] who reported a smaller increase in pressure per unit of time in the left ventricle of the heart of calves sedated by administration of xylazine. It is possible that the increased peripheral resistance caused by xylazine also has a negative effect on blood flow velocity.[9,10]

Sedation achieved by administration of xylazine resulted in a noticeable increase in the duration of diastole. This was caused by bradycardia, during which the ratio of systole to diastole shifts toward the latter.[11,12] The mean blood flow velocity decreased markedly as a result of prolonged diastole, decreased cardiac output, and arterial dilatation during xylazine-induced sedation.

Maximum velocity of retrograde blood flow increased during sedation presumably because of increased peripheral resistance and vasodilatation. This has been interpreted by a number of authors as an indication of reduced tension of the vessel wall.[9,13] In human medicine, duplex ultrasonography has been used to investigate the effects of various drugs on flow-time volume in the common carotid artery[14] and abdominal vasculature.[15] We believe that the same methods can be used to evaluate drug effects on the cardiovascular system in cattle.

Overall, the velocity spectrum of the Doppler tracings for the external jugular vein was wider than the velocity spectrum of the tracings for the common carotid artery. The reason is that the difference between the flow velocities at the center and periphery of a vessel increases with decreasing blood flow velocity. Specifically, the velocity spectrum was markedly increased during inspiration, which was associated with an increased centripetal venous blood flow, indicating turbulence. After administration of xylazine, flow-time volume in the external jugular vein decreased by approximately 25%, which corresponded to the decrease in blood flow in the common carotid artery in the sedated cows. The decrease in jugular blood flow was associated with a marked increase in venous filling. Decreased cardiac output without blood loss results in an increased volume of blood in the large veins.[16] Furthermore, respiratory depression caused by xylazine-induced sedation may have had an additional negative effect on venous return.[17]

We documented the effects of xylazine-induced sedation on blood flow patterns in the common carotid artery and external jugular vein of cattle. We believe that the results of the study reported here can be used as reference values when evaluating cattle with diseases that affect blood flow in the common carotid artery and external jugular vein.

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