Effect of a 30-minute infusion of dobutamine hydrochloride on hind limb blood flow and hemodynamics in halothane-anesthetized horses

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Objective—To evaluate the hemodynamic effects of dobutamine hydrochloride (0.5 µg/kg of body weight/min) in halothane-anesthetized horses.

Animals—6 adult Thoroughbred horses.

Procedure—Anesthesia was induced by use of romifidine (100 µg/kg) and ketamine (2.2 mg/kg), IV. Anesthesia was maintained by halothane (end-tidal concentration 0.9 to 1.0%). Aortic, left ventricular, and right atrial pressures were measured, using catheter-mounted strain gauge transducers. Cardiac output (CO), velocity time integral, maximal aortic blood flow velocity and acceleration, and left ventricular preejection period and ejection time were measured from aortic velocity waveforms obtained by transesophageal Doppler echocardiography. Velocity waveforms were recorded from the femoral vessels, using Doppler ultrasonography. The time-averaged mean velocity and early diastolic deceleration slope (EDDS) were measured. Pulsatility index (PI) and volumetric flow were calculated. Microvascular perfusion was measured in the semimembranosus muscles by laser Doppler flowmetry. Data were recorded 60 minutes after induction of anesthesia (control) and at 15 and 30 minutes after start of an infusion of dobutamine (0.5 µg/kg/min).

Results—Aortic pressures were significantly increased during the infusion of dobutamine. No change was observed in the indices of left ventricular systolic function including CO. Femoral arterial flow significantly increased, and the PI and EDDS decreased. No change was observed in the femoral venous flow or in microvascular perfusion.

Conclusions and Clinical Relevance—At this dosage, dobutamine did not alter left ventricular systolic function. Femoral blood flow was preferentially increased as the result of local vasodilatation. The lack of effect of dobutamine on microvascular perfusion suggests that increased femoral flow is not necessarily associated with improved perfusion of skeletal muscles. (*Am J Vet Res* 2000;61:1282–1288)

Dobutamine hydrochloride has been recommended for the treatment of hypotension in anesthetized horses.[1] It is a potent β-1 adrenergic agonist that effectively restores blood pressure in hypotensive dogs and human patients by improving myocardial contractility and increasing **cardiac output (CO)**.[2-8] Similar effects have been found in anesthetized horses.[1,9-11] Results of a clinical retrospective study indicate that administration of dobutamine to horses during general anesthesia appears to decrease the severity of postanesthetic myopathy. However, the incidence of postanesthetic myopathy was not reduced.[12] This finding may be the result of the poor correlation between arterial blood pressure and peripheral perfusion described in humans[2] and supports the need to measure peripheral blood flow directly.

Results of a recent study on dobutamine infusion in horses (4 µg/kg of body weight/min) indicate that there are adverse effects on cardiac function during a 60-minute infusion.[11] In that study, supraventricular tachycardia was observed in 2 of the 6 horses studied. The authors also reported that sustained administration of dobutamine at this dosage resulted in continued changes in hemodynamic function. The CO and indices of left ventricular systolic contractility (**maximal rate of rise of left ventricular pressure [LVdp/dt$_{max}$], maximal aortic blood flow velocity [V$_{max}$], maximum acceleration of aortic blood flow [dvdt$_{max}$]**) continued to increase, whereas ejection time and preejection period continued to decrease throughout the infusion. The purpose of the study reported here was to determine the central and peripheral hemodynamic effects in anesthetized horses of a lower dosage dobutamine infusion (0.5 µg/kg/min) for 30 minutes. This dosage is used in several clinics in the United Kingdom to support arterial blood pressure during clinical anesthesia.

Materials and Methods

Six adult Thoroughbred and Thoroughbred crossbred horses weighing 450 to 650 kg were included in our study. There were 4 geldings and 2 mares between 4 and 6 years of age. The right carotid artery of each horse was relocated to a subcutaneous position under general anesthesia at least 12 weeks before our study. The study was approved by the ethics committee of the Animal Health Trust and performed under Home Office Project License PPL 80/1017.

Before anesthesia, food, but not water, was withheld for 12 hours. Horses were sedated with 100 µg of romifidine[a]/kg by IV injection through a jugular catheter. Five minutes later, anesthesia was induced by 2.2 mg of ketamine[b]/kg, IV. After induction of anesthesia, endotracheal intubation was performed, and the horses were hoisted onto a padded operating

Received Jun 1, 1999.
Accepted Sep 28, 1999.

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table and positioned in left lateral recumbency. Horses were positioned so that the upper and lower limbs were parallel, and the lower limb was slightly cranial to the upper limb. Anesthesia was maintained with halothane delivered in oxygen via a large-animal anesthetic circuit.[c] The halothane concentration in the respired gases was measured, using a calibrated piezoelectric agent monitor.[d] End-tidal concentrations were maintained at 0.9 ± 0.1%, which is equivalent to 1.2 times the minimum alveolar concentration.[13] Intermittent positive-pressure ventilation was used to maintain $Paco_2$ between 40 and 50 mm Hg.

Immediately after induction of anesthesia, a 160-cm long 3.75 MHz transesophageal echocardiographic probe was inserted into the esophagus via the ventral nasal meatus of the right nostril. The probe was used in conjunction with an ultrasound system.[e] The probe was advanced into the esophagus until a long axis view of the left ventricular outflow tract and aorta was obtained, using 2-dimensional ultrasonography.[f] The Doppler sample volume was placed in the center of the vessel above the aortic valve. Aortic velocity waveforms were recorded, using high pulse repetition frequency mode with ultrasound emitted at 2.5 MHz. Left ventricular **preejection period (PEP)**, **ejection time (ET)**, **velocity time integral (VTI)**, V_{max}, and $dvdt_{max}$ were measured from the aortic flow velocity waveforms.[14] The CO was also calculated.[15]

Left ventricular and aortic blood pressures were measured, using strain gauge transducers[g] mounted on an 8 F woven dacron catheter. One transducer was located on the distal end of the catheter, and the other was 12 cm proximal. The catheter was inserted into the subcutaneous right carotid artery, using the Seldinger technique. The catheter was advanced until the pressure traces indicated that the distal transducer was in the left ventricle, and the proximal transducer was in the aorta. Right atrial pressure was measured, using a strain gauge transducer[h] mounted on the distal end of a 7 F woven dacron catheter. The catheter was inserted into the right jugular vein, using the Seldinger technique. The catheter was advanced until the pressure trace indicated the transducer was in the right ventricle. The catheter was then slowly withdrawn until the pressure trace indicated that the transducer had entered the right atrium and was then withdrawn a further 3 cm. A universal amplifier[i] supplied the bridge excitation voltage to each transducer. Voltage output from each transducer was digitized at 500 Hz and recorded, using data acquisition software[j] on a computer. The transducers were calibrated against a mercury manometer at 0 and 100 mm Hg. The response of the transducers was linear within the measured range. A base apex ECG was obtained, and the signal was digitized and stored by the data acquisition system.[k] Mean heart rate, mean right atrial pressure, systolic, diastolic, and mean aortic pressure, and left ventricular **end-diastolic pressures (EDP)** were calculated from 20 seconds of data recorded simultaneously with aortic ultrasound data collection. The $LVdp/dt_{max}$ was obtained by differentiation of the left ventricular pressure signal. **Systemic vascular resistance (SVR)** was calculated.[16]

Ultrasonography of femoral vessels was performed, using a 7.5-MHz annular-phased array transducer positioned over the femoral groove as proximal as possible within the inguinal region. Two-dimensional images of the femoral vessels were obtained, using ultrasound emitted at a frequency of 5 MHz. Imaging depth was set to 9 cm. Instrument settings were adjusted to delineate the vessel walls from the surrounding tissues. The Doppler sample volume was positioned centrally within the vessel, and the sample volume cursor was adjusted to align with the vessel walls and blood flow. The angle between the sample volume cursor and the ultrasound beam was measured by the ultrasound system, and velocity calculations were adjusted accordingly. The probe was manipulated in the inguinal region until the angle between the vessel and the ultrasound beam was 60°. The sample volume was set at the maximum length of 5 mm. Once the sample volume was in position, Doppler studies were performed in low-pulse repetition frequency mode, using ultrasound emitted at a frequency of 4 MHz. The quality of the velocity waveforms was assessed from the clarity of the visual and audible signal. **Time-averaged mean velocity for the entire cardiac cycle (TAV)**, **component a (TaVa)**, **component b (TaVb)**, volumetric flow, **pulsatility index (PI)**, and **early diastolic deceleration slope (EDDS)** were calculated from arterial velocity waveforms.[17] Time-averaged mean velocity and volumetric flow were also calculated. Two-dimensional images of the vessels were recorded on VHS videotape for measurement of vessel diameter. Femoral and aortic blood-flow velocity waveforms were digitized, using an analysis and archiving program.[f] Measurements were made from 5 consecutive cardiac cycles. Contour of the arterial and velocity waveforms were also assessed.[17]

Laser Doppler flowmetry (LDF) was performed, using a dual channel flowmeter[l] with a wavelength of 780 nm. Single fiber probes[m] 0.5 mm in diameter were placed in the semimembranosus muscles of the left and right hind limb. The probes were inserted via 2 20-gauge catheters inserted to a depth of 5 cm within 5 to 10 minutes of the induction of anesthesia. Each probe was securely taped to the hub of the catheter, and the probe connector was fixed to an external support to prevent movement. Flux, expressed in blood perfusion units, and tissue remittance were displayed, digitized, and recorded. Sudden changes in the percentage of tissue remittance were used to detect probe movement. Microvascular perfusion was calculated as the mean blood perfusion units recorded during the 5-minute period coinciding with the Doppler studies of the femoral vessels. For each data collection point, this was then expressed as a percentage of the mean value recorded 60 minutes after the induction of anesthesia (control).

Venous blood was collected from a cephalic venous catheter for measurement of PCV and total plasma protein concentration. Packed cell volume was determined by microcentrifugation. Plasma protein concentration was determined, using a refractometer.

Data collection—Aortic velocity waveforms were recorded 60 minutes after induction of anesthesia (control) and 15 and 30 minutes after the start of the dobutamine infusion (0.5 µg/kg/min). Data were also collected 15 minutes after termination of the infusion. Femoral vessel blood-flow data were collected 60 minutes after induction of anesthesia (control) and then at 15 and 30 minutes of the dobutamine infusion. Intermittent positive-pressure ventilation was discontinued during collection of all ultrasound data. Measurements of cardiovascular function were derived from heart rate and pressure measurements recorded 60 minutes after induction of anesthesia and 15 and 30 minutes after start of dobutamine infusion. Measurements were also determined 15 minutes after termination of the infusion. Microvascular perfusion was calculated 60 minutes after commencement of anesthesia and then 15 and 30 minutes after infusion of dobutamine. Packed cell volume and total plasma protein were measured 60 minutes after induction of anesthesia and 15 and 30 minutes after start of dobutamine infusion.

Statistical analysis—Data obtained at each sample time were compared, using Wilcoxon signed rank test. Results were considered to be significantly different when there was a value of $P < 0.05$.

Results

Systolic, diastolic, and mean aortic blood pressures were significantly increased at 15 and 30 minutes after

Table 1—Median (range) measurements of cardiovascular function recorded in 6 halothane-anesthetized horses before and after an infusion of dobutamine

Variable	Before*	Time from start of infusion		Time from end of infusion
		15 min after	30 min	15 min
V_{max} (m/s)	0.84 (0.70–0.98)	0.84 (0.67–0.96)	0.81 (0.72–1.17)	0.86 (0.69–1.06)
$dvdt_{max}$ (m/s/s)	5.09 (4.17–6.20)	4.71 (4.28–7.01)	7.23[a,b] (5.20–10.3)	7.26[a,b] (4.04–9.33)
PEP (s)	0.23 (0.20–0.24)	0.22 (0.13–0.24)	0.20[a,b] (0.15–0.23)	0.19[a,b] (0.17–0.22)
ET (s)	0.49 (0.46–0.50)	0.49 (0.46–0.50)	0.49 (0.45–0.54)	0.50 (0.46–0.54)
VTI (cm/s)	29.6 (22.6–31.2)	27.1 (21.8–29.8)	29.1 (23.6–35.4)	27.4 (23.6–36.3)
CO (L/min)	35.7 (20.8–50.5)	33.8 (24.8–52.9)	36.0 (22.7–60.6)	35.3 (23.0–52.3)
Heart rate (bpm)	30.1 (27.0–42.3)	29.0 (24.8–44.5)	28.8 (25.0–44.4)	28.4 (25.0–42.8)
ABP_{sys} (mm Hg)	91.8 (83.0–103)	102[a] (82.8–108)	106[a,b] (89.2–110)	104[a] (89.6–112)
ABP_{dias} (mm Hg)	66.1 (62.0–81.6)	77.6[a] (71.6–85.6)	79.6[a] (64.8–86.0)	77.9[a] (65.5–87.5)
ABP_{mean} (mm Hg)	80.0 (74.4–93.8)	89.3[a] (72.5–98.2)	94.3[a,b] (77.8–99.8)	92.5[a] (78.3–102)
RAP_{mean} (mm Hg)	11.4 (6.89–20.8)	13.1 (8.50–22.5)	13.4[a,b] (9.34–22.5)	12.7[a] (9.20–23.0)
LV EDP (mm Hg)	29.5 (19.3–37.3)	30.2 (17.6–43.0)	31.5 (19.9–41.9)	32.0 (20.3–42.0)
$LVdp/dt_{max}$ (mm Hg/s)	412 (335–544)	455 (425–733)	443 (211–657)	412 (335–544)
SV (L)	1.19 (0.77–1.25)	1.14 (1.00–1.19)	1.21 (0.91–1.42)	1.21 (0.92–1.21)
SVR (dyneos/cm5)	157 (113–266)	180 (134–248)	184 (117–275)	181 (115–270)
PCV (%)	38.5 (38.0–42.0)	43.0[a] (40.0–45.0)	45.0[a,b] (43.0–48.0)	
TPP (g/L)	58.5 (53.0–66.0)	57.0 (53.0–64.0)	57.5 (53.0–67.0)	

*Obtained 60 minutes after the induction of anesthesia and before infusion of dobutamine.
[a]Significantly different ($P < 0.05$) from control value. [b]Significantly different ($P < 0.05$) from data recorded 15 minutes after onset of infusion.
V_{max} = Maximum aortic blood flow velocity. $dvdt_{max}$ = Maximum acceleration of aortic blood flow. PEP = Left ventricular preejection period ET = Left ventricular ejection time. VTI = Left ventricular velocity time integral. CO = Cardiac output. ABP_{sys} = Systolic aortic blood pressure. ABP_{dias} = Diastolic aortic blood pressure. ABP_{mean} = Mean aortic blood pressure. RAP_{mean} = Mean right atrial pressure. LV EDP = Left ventricular end-diastolic pressure. $LVdp/dt_{max}$ = Maximum rate of rise of left ventricular pressure . SV = Stroke volume. SVR = Systemic vascular resistance. TPP = Total plasma protein.

Table 2—Median (range) blood-flow measurements recorded from the right and left femoral artery and vein and semimembranosus muscle before (control) and 15 and 30 minutes after the start of the dobutamine infusion

Variable	Right hind limb			Left hind limb		
	Before (control)	15 min after	30 min after	Before (control)	15 min after	30 min after
Femoral artery						
Vessel diameter (mm)	13.6 (11.2–15.5)	13.5 (11.7–15.2)	13.6 (12.0–15.0)	12.8 (11.6–14.6)	13.0[d] (11.0–14.2)	13.5 (11.0–14.2)
TAV (cm/s)	8.85[c] (6.15–11.0)	11.2[a] (6.95–15.2)	12.7[a] (9.82–16.5)	13.6[c] (9.91–14.9)	12.9 (8.75–17.4)	15.6[a,b] (13.8–22.1)
TaVa (cm/s)	34.4 (27.7–39.3)	30.6[a] (26.1–38.8)	32.5[b] (27.8–40.3)	31.4 (26.3–40.6)	28.4[a] (23.0–32.8)	33.4[a] (22.4–34.4)
TaVb (cm/s)	0.54[c] (−6.24–4.87)	4.65[a,c] (−3.93–9.04)	6.75[a,c] (0.33–9.52)	7.12[c] (2.38–8.68)	8.70[a,c] (2.25–12.2)	11.1[a–c] (6.31–15.2)
Vmax (cm/s)	70.0 (56.6–88.2)	62.9 (48.7–80.2)	63.7 (59.4–100.6)	67.6 (56.6–75.6)	61.0[a] (43.0–58.1)	71.4 (48.0–75.4)
Flow (ml/min)	583[c] (540–1,248)	947[a] (660–1,479)	1,122[a,b] (732–1,593)	984[c] (807–1,408)	894 (740–1,586)	1275[a,b] (964–1,898)
EDDS (cm/s/s)	243 (131–300)	186 (107–289)	198[a] (114–250)	169 (142–273)	156[a] (115–256)	171 (107–220)
PI	9.18 (4.63–19.0)	5.94 (2.64–15.2)	6.25 (3.02–15.7)	4.20 (3.38–9.89)	3.74 (3.10–14.7)	3.31 (2.07–5.23)
Femoral vein						
Vessel diameter (mm)	17.8 (10.5–19.8)	17.6 (10.5–19.9)	17.8 (10.5–20.5)	14.3 (9.40–20.3)	14.3 (9.80–22.1)	13.8 (9.80–20.3)
TAV (cm/s)	12.5 (4.47–22.9)	11.1 (6.26–33.0)	12.0 (9.79–23.1)	12.5 (5.29–16.8)	8.42[d] (3.68–16.7)	7.91 (4.89–43.5)
Flow (ml/min)	1,195 (826–1,197)	1,686 (1,076–2,090)	1,610 (1,073–2,380)	748 (579–2,194)	757[d] (605–886)	983 (363–2,389)
Semimembranosus muscle						
Perfusion (BPU)	3.67 (1.42–9.68)	3.00 (1.28–7.85)	3.28 (1.39–8.60)	3.55 (2.13–7.74)	3.35 (2.27–6.29)	3.17 (2.38–5.89)
Perfusion (%)	100	85.3 (62.0–105)	90.3 (67.0–162)	100	94.7 (76.2–107)	89.8 (76.1–112)

[a]Significantly different ($P < 0.05$) from control. [b]Significantly different ($P < 0.05$) from data recorded 15 minutes after the start of the infusion. [c]Significant difference ($P < 0.05$) between left and right vessels.
TAV = Time-averaged mean velocity. TaVa = Time-averaged mean velocity for component a. TaVb = Time-averaged mean velocity for component b. Flow = Volumetric flow. EDDS = Early diastolic deceleration slope. PI = Pulsatility index.

the start of the infusion of dobutamine (0.5 µg/kg/min; **Table 1**). Mean right atrial pressure was significantly increased at 30 minutes after the start of the infusion. Aortic and right atrial blood pressures were significantly higher than baseline values 15 minutes after cessation of the infusion. Then, $dvdt_{max}$ and left ventricular PEP were significantly increased 30 minutes after the start of the infusion and remained significantly increased 15 minutes after the infusion was discontinued. There was no significant change in V_{max}, left ventricular ET, VTI, CO, stroke volume, SVR, left ventricular EDP, and $LVdp/dt_{max}$. Packed cell volume was significantly increased at 15 and 30 minutes after start of the infusion.

In the right artery, TAV, TaVb, and volumetric flow were significantly increased in 15 and 30 minutes and TaVa was significantly decreased in 15 minutes after the start of the dobutamine (**Table 2**). In the left artery, TaVa was significantly increased 15 and 30 minutes after start of infusion, whereas TAV and volumetric flow were only significantly increased 30 minutes after start of infusion (Table 2). Diameters of both femoral arteries were not significantly different. Decreased EDDS and PI were observed in both femoral arteries. The EDDS was significantly decreased in the left artery 15 minutes after start of the infusion and in the right artery 30 minutes after start of infusion. Pulsatility index was not significantly different. There were no significant changes in venous vessel diameter, TAV, or volumetric flow during the infusion of dobutamine.

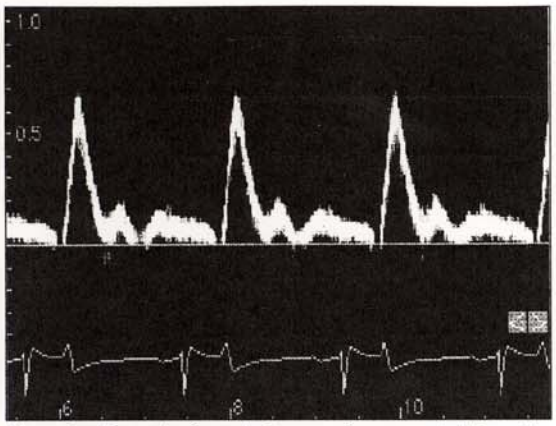

Figure 1—Example of a velocity waveform recorded from the left femoral artery before infusion of dobutamine hydrochloride. Features of the waveform include absence of early diastolic wave reflection and complete forward flow throughout diastole.

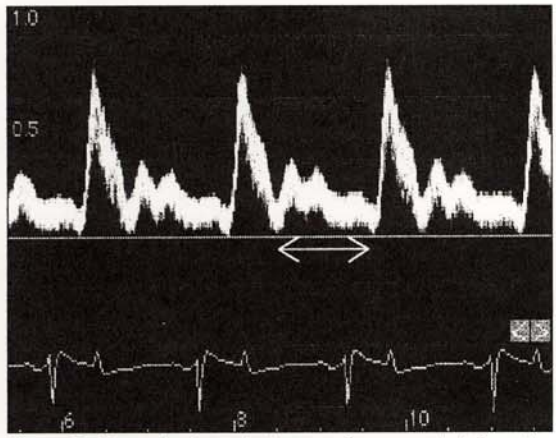

Figure 2—Example of a velocity waveform recorded from the left femoral artery 30 minutes after onset of infusion of dobutamine hydrochloride. Features include increased amounts of forward flow during diastole (double arrow).

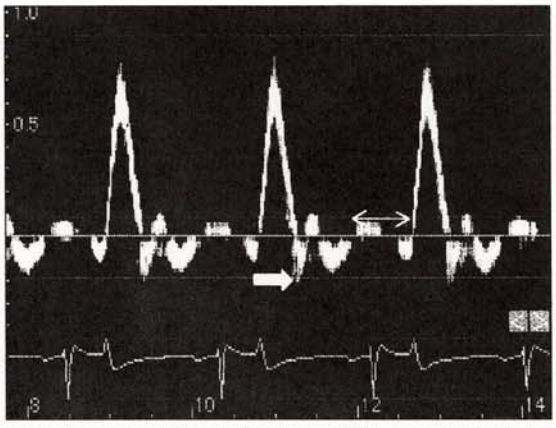

Figure 3—Example of a velocity waveform recorded from the right femoral artery before infusion of dobutamine hydrochloride. Features of the waveform include early diastolic reversal of flow (block arrow) and incomplete forward flow during mid-late diastole (fine arrow).

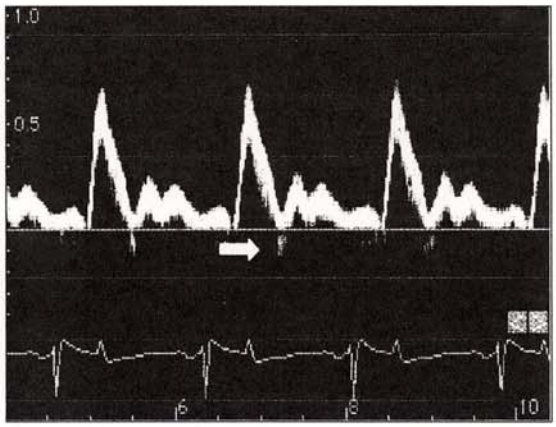

Figure 4—Example of a velocity waveform recorded from the right femoral artery 30 minutes after the onset of infusion of dobutamine hydrochloride. Features of the waveform include reduced amounts of flow reversal in early diastole (block arrow) and increased amounts of forward flow during diastole.

There were no changes in the perfusion of the semimembranosus muscles recorded, using LDF.

The contours of the left femoral arterial velocity waveform were observed to alter during administration of dobutamine with increased amounts of forward flow throughout diastole in all horses (**Fig 1 and 2**). Absence of early diastolic flow reversal was observed in 3 horses, where early diastolic flow reversal was present in the left artery before infusion of dobutamine. Changes in waveform contour in the right artery included decreased flow reversal in early diastole and increased forward flow throughout diastole (**Fig 3 and 4**). In 4 horses, there was complete absence of diastolic flow reversal after dobutamine infusion. No changes in the contour of the venous waveform were observed during the infusion of dobutamine.

Differences in measurements recorded from the left and right femoral vessels were observed. Before infusion of dobutamine, TAV, TaVb, and volumetric flow were significantly higher in the left (dependent) femoral artery than the right (nondependent) femoral artery. Arterial velocity waveforms from the left femoral artery had less early diastolic flow reversal and larger amounts of forward flow throughout diastole, compared with the right artery (Fig 1 and 3). With the exception of TaVb, these differences were not apparent during dobutamine infusion.

Discussion

Dobutamine administration at 0.5 µg/kg/min is commonly used clinically in horses to increase arterial blood pressure. However, results of our study revealed minimal effects of a 30-minute infusion of dobutamine (0.5 µg/kg/min) on indices of left ventricular systolic function despite significant increases in aortic blood pressure. This is in contrast to similar studies in anesthetized horses, where a prolonged infusion of 4 µg/kg/min caused significant increases in $LVdp/dt_{max}$, $dvdt_{max}$, and CO in association with a reduction in left ventricular PEP and ET,[11] suggesting a beneficial effect

on left ventricular contractility. In our study, $LVdp/dt_{max}$, $dvdt_{max}$, and V_{max} were unchanged during a 30-minute infusion of 0.5 µg/kg/min. Only a significant reduction in left ventricular PEP was suggestive of improved left ventricular systolic function.[18] When aortic blood pressure increases without concurrent increases in CO, as occurred in our study, an increase in SVR would be expected. However, calculated SVR was not significantly increased during the 30-minute infusion of 0.5 µg/kg/min of dobutamine. There was a trend for the median value of SVR to increase throughout the infusion, and the failure to detect a significant increase may be related to the small number of horses and the resultant low statistical power of the analyses used in our study. The low dosage used in our study may also be responsible for the lack of change in measured cardiovascular function.

Results of work by Young et al[11] indicate a temporal effect of sustained infusions of 4 µg/kg/min in anesthetized horses, using the same regime for premedication and induction of anesthesia. In our study, with the exception of increased aortic pressure and right atrial pressure over time, temporal effects of a lower dosage of dobutamine infusion for a shorter duration were not detected. It is possible that had the infusion been maintained for a longer period, as in the studies of Young et al,[11] cumulative effects may have been evident. The ability to detect temporal changes may also have been limited by the small number of horses. In agreement with previous studies,[15,19,20] a number of hemodynamic variables had not returned to baseline values 15 minutes after cessation of the infusion.

In contrast, femoral arterial blood flow was significantly increased during the administration of dobutamine. As no changes were observed in vessel diameter, the increased arterial flow was the result of increased TAV. Analysis of the arterial waveform contour revealed decreased amounts of early diastolic flow reversal and increased forward flow during mid-late diastole during the infusion of dobutamine. In addition, early diastolic deceleration and PI were decreased. These changes are associated with peripheral arteriolar vasodilatation and decreased regional vascular resistance[21,22] and suggest that 0.5 µg/kg/min dobutamine decreased femoral vascular resistance. This decrease in femoral vascular resistance was not accompanied by a decrease in SVR. Since EDDS and PI are indices of vascular resistance, direct measurements of femoral vascular resistance would be required to confirm our findings. However, increased arterial blood flow in the absence of changes in CO and SVR suggests that decreased femoral vascular resistance was causing preferential distribution of CO to the femoral vascular bed. These data also indicate that SVR cannot be used to infer the net effect of an agent on individual vascular beds.[16]

Femoral venous flow did not change during infusion of dobutamine despite increases in femoral arterial flow. There is no obvious explanation for this finding. However, results of previous studies on the repeatability of femoral blood flow measurements in anesthetized horses indicate higher within-horse variability in venous flow measurements as the result of errors in measurement of vessel diameter and TAV.[17] High within-horse variability limits the ability of a technique to detect changes in a measurement, and this may be a possible explanation for the present findings. The small number of horses used in our study may also have limited the ability to detect changes in venous flow. Median values of venous flow tended to increase during the dobutamine infusion, and the use of more horses may have revealed a significant increase in this variable.

Before administration of dobutamine, higher mean velocity and volumetric flow were observed in the left (dependent) artery, compared with the right (nondependent) artery. In addition, there was less flow reversal and more forward flow during mid-late diastole (Fig 1 and 3) in the left artery, suggesting lower peripheral resistance.[21,22] Higher arterial blood flow in the left (dependent) artery contrasts with results of other studies, where microvascular perfusion in the dependent limb was observed to be similar[23,24] or lower than perfusion in the nondependent hind limb.[n] In our study, microvascular perfusion in the semimembranosus muscle was recorded, using LDF. This technique is limited to the measurement of relative flow at a single site and, thus, microvascular flow in the right and left hind limbs could not be compared directly.

As Doppler ultrasonography records flow within the conducting vessels, the discrepancy between femoral flow in our study and reported microvascular perfusion in the hind limbs could be explained by uneven distribution of flow within the hind limb. In other species, capillary collapse, associated with high tissue pressures, causes communications between the small arteries and veins within the connective tissue surrounding the muscle fibers to open. Thus, arterial and venous flows are maintained while capillary flow is reduced.[25,26] High **intracompartmental muscle pressures (ICMP)** described in the dependent limbs of anesthetized horses[27,28] could potentially produce uneven distribution of femoral flow. Thus, increased femoral arterial blood flow during dobutamine administration may not necessarily cause increased skeletal muscle perfusion.

Differences in hydrodynamics provide a possible explanation for the differential perfusion of the dependent and nondependent femoral arteries in our study. In lateral recumbency, the nondependent limb is elevated above the heart. The resultant decrease in hydrostatic pressure reduces the internal pressure in the arteries as height above the heart increases. Decreased internal pressure results in increased transmural pressure and associated vessel collapse and increased resistance to flow.[29] Low central arterial pressures, caused by intraoperative hypotension, further reduce internal pressures in the elevated limb, promoting further vessel collapse and reduction in blood flow.[30,31] Thus, the lower flow and higher vascular resistance detected in the right (nondependent) femoral arteries before the administration of dobutamine may have resulted from the combined effects of limb elevation and low central pressures. The increase in mean aortic pressure during infusion of dobutamine could have decreased the effects of hydrostatic pressure and may have equalized the flow in the left and right femoral arteries.

Microvascular flux recorded from the semimembranosus muscles did not change during the infusion of dobutamine despite significant increases in femoral arterial blood flow. This supports the possibility of uneven distribution of perfusion within the hind limb[32] as the result of capillary collapse in association with high ICMP. However, it has been shown that once a capillary has collapsed, the perfusion pressure required to open the capillary is significantly higher than the perfusion pressure needed to maintain perfusion before the capillary collapsed.[26] It is possible that while femoral arterial pressure increased during dobutamine administration, it was insufficient to promote detectable changes in microvascular perfusion. To determine whether regional differences in the distribution of blood flow do occur within the hind limbs of anesthetized horses, measurement of microvascular perfusion at numerous intramuscular sites would be necessary.

Microvascular flow is also affected by changes in PCV.[32] Increases in microcirculatory PCV with resultant increases in viscosity are detrimental to flow in small vessels.[33,34] During the infusion of dobutamine, PCV significantly increased. The resultant increases in viscosity may have impeded capillary flow despite increases in femoral arterial blood flow. Although arterial oxygen delivery is reportedly increased by the high PCV during dobutamine administration,[o] the detrimental effects of increased viscosity limit oxygen delivery to the tissues. As many of the agents used to increase arterial blood pressure in anesthetized horses are reported to increase PCV,[35] detailed studies of the effects of changes in PCV on microvascular perfusion are warranted.

Results of our study indicate the central and peripheral hemodynamic effects of a constant infusion of dobutamine (0.5 µg/kg/min) in normotensive horses under laboratory conditions. It is possible that the effects of dobutamine administered at this lower dosage may differ in hypotensive horses. Thus, further studies are required in clinical horses with hypotension.

In conclusion, the infusion of dobutamine at 0.5 µg/kg/min for 30 minutes had minimal effects on left ventricular systolic function. However, it is possible that improvements may have occurred if the duration of the infusion was longer. There was a significant increase in mean aortic pressure despite the absence of change in left ventricular systolic function. These data suggest that the increased arterial blood pressure produced by the low dosage dobutamine infusion was not mediated by changes in cardiac contractility or CO. Dobutamine was effective in increasing femoral blood flow. This was associated with decreased femoral vascular resistance, despite an absence of effect on SVR. However, increased femoral arterial blood flow was not accompanied by increased perfusion in the semimembranosus muscle suggesting that there may be uneven distribution of blood flow to muscle. These data highlight the need for studies of microvascular flow in anesthetized horses. The results of this study also show that central indices of left ventricular function, CO, mean arterial pressuer and SVR can not be used to infer the effects of agents on regional perfusion.

[a]Sedivet, Boehringer Ingelheim, Bracknell, UK.
[b]Vetalar, Pharmacia & Upjohn SA, Luxembourg.
[c]LAVC-2000, JD Medical, Phoenix, Ariz.
[d]Lamtec 605, pneuPAC Ltd, Luton, UK.
[e]GE Ultrasound, Bedford, UK.
[f]Echopac, Vingmed Sound, Horten, Norway.
[g]Gaeltec Ltd, Dunvegan, Scotland.
[h]Millar Instruments Inc, Houston, Tex.
[i]Gould Recording Systems, Gould Electronics Inc, Eastlake, Ohio.
[j]Pon-e-mah digital acquisition, analysis, and archive systems, Linton Instrumentation, Diss, UK.
[k]Nihon Khoden Europe Ltd, Brentword, UK.
[l]Oxford Optronix, Magdalen Center, Oxford, UK.
[m]SF100 fiber optic probes, Oxford Magdalen Center, Oxford, UK.
[n]Branson KR, Benson GJ, Thurmon JC, et al. Comparison of isoflurane and halothane in horses: hemodynamics, tissue oxygen delivery and extraction (abstr). *Vet Surg* 1992;21:80.
[o]Wertz EM, Dunlop DI, Wagner AE, et al. Cardiovascular and oxygenation responses to dobutamine and dopamine in halothane anesthetized horses (abstr). *Vet Surg* 510–502.

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