Pressure Variations in Small Veins in the Hindleg of the Dog

By Mary P. Wiedeman, Ph.D.

During measurements of pressure in the small veins of a dog's hindleg, it was observed that fluctuations in pressure, associated with respiration, varied considerably from animal to animal. In some instances, venous pressure fell during the inspiratory phase; in other instances, venous pressure rose. In addition, spontaneous pressure changes, seemingly independent of respiratory movements, were occasionally seen. It seemed possible that some factor, or factors, other than thoracic pressure changes during respiration might be involved in varying small vein pressure.

It has been stated that respiratory waves seen in small veins were probably transmitted through the arterial side and that they followed in time the respiratory waves seen in large systemic arteries. In a more recent paper, Irisawa and Rushmer recorded venous and lymphatic pressures in the dog's leg and noted that oscillatory changes in these pressures were associated with respiration and that an increase in pressure in these vessels coincided with expiration.

To clarify the origin of pressure variations, as seen in the small cutaneous veins in the hindleg of the dog, simultaneous recordings were made of small vein pressure, direction of intra-abdominal pressure changes, small and large artery pressure, and respiratory movements.

Methods

Mongrel dogs were anesthetized with sodium pentobarbital (38 mg./Kg.), injected intravenously and were placed in a supine position.

Polyethylene tubing, with an outside diameter of about 1 mm., was introduced into a small vein and a small artery in the following manner: A small vein near the ankle was exposed and ligated. An incision was made distal to the ligature and polyethylene tubing filled with a 1 per cent heparin solution was inserted through the cut and carefully pushed forward until the tip was in or very near the toes. The tubing was then withdrawn 1 or 2 mm. until blood was seen to flow freely back through the tubing. This was considered adequate assurance that the peripherally directed cannula was not wedged in the vein. Another cannula was then inserted into the vein with its tip directed centrally. It was carefully pushed toward the vein orca for several centimeters. The appearance of blood in the cannula when the stopcock was opened to atmosphere indicated that its tip was not obstructed by the vein wall or a valve. The cannula was tied securely at its point of entrance into the vein. Occasionally the centrally directed cannula was placed in a small vein other than the 1 in which the distally directed cannula was placed. These cannulas were alternately connected to a P 23BB Statham strain gage (range 0 to 5 cm. Hg) throughout the experiment.

For purposes of recording, all venous and arterial pressures were set at zero on the same baseline. When it was seen that the small artery pressure in 1 leg and the femoral artery pressure in the opposite leg were identical in height, form, and behavior throughout all procedures except 1, they were subsequently recorded at the same amplification which caused them to be superimposed.

Direction of intra-abdominal pressure change was determined by the insertion of a multiperforated polyethylene catheter through the linea
Cyclic pressure changes in a small vein. A. Cannula in small vein directed toward the foot. SVP = 29 mm Hg. B. Cannula in small vein directed centrally. SVP = 12 mm Hg.; R = respiration; SVP = small vein pressure; IAP = intra-abdominal pressure; FAP + SAP = femoral artery pressure with small artery pressure superimposed. Arterial pressure is indicated by the numbers. The base line represents zero for venous and arterial pressures.

Respiratory movements were recorded through a strain gage attached to a pneumograph around the chest. This gage was arranged to give an upward movement on the recorder during inspiration. Results

Normal Variations in Pressure

In 29 animals, venous pressure ranged between 2.7 and 58.4 mm Hg, when the cannula was directed toward the foot. The average pressure was 23.5 mm Hg, while the pressures most frequently seen were between 6 to 10 mm Hg. The pressures from the centrally directed cannuulas were generally lower, ranging between 1.4 and 24.4 mm Hg, with an average of 8.7. The pressure most frequently seen was also between 6 to 10 mm Hg (fig. 1).

Contrary to earlier expectations, it was observed that rhythmic small vein pressure changes were more closely related to intra-abdominal pressure changes resulting from respiratory movements than to thoracic alterations during inspiration or expiration. In 73 per cent of the cases, venous pressure and intra-abdominal pressure rose during inspiration (fig. 2A). In the remaining 27 per cent, venous pressure and intra-abdominal pressure fell markedly just before inspiration began, and showed a very slight rise at the peak of inspiration followed by a sharp rise that was sustained during expiration (fig. 2B). On closer inspection, it was found that the fall in intra-abdominal and venous pressure that just preceded inspiration was coincidental with relaxation of abdominal muscles contracted throughout expiration. Gilfoil, Youmans, and Turner have recently described an "abdominal compression reaction" in anesthetized dogs. They postulate that it is of importance in maintaining the return of blood to the heart.

Further evidence of the dominant influence of intra-abdominal pressure on hindlimb small
Figure 3
A. Small vein pressure and intra-abdominal pressure waves in the absence of respiratory movements. B. Spontaneous pressure waves in a small vein. R = respiration; SVP = small vein pressure; IAP = intra-abdominal pressure; FAP + SAP = femoral artery pressure with small artery pressure superimposed. Pressure in mm. Hg is indicated by the numbers. Small vein pressure is written on the right-hand side of the figure. Femoral and small artery pressure on the left-hand side of the figure. The base line represents zero for venous and arterial pressures.

vein pressure is that both pressures changed in the same direction in the absence of respiratory movements. In 9 instances in 20 trials (45 per cent), similar changes were seen in the direction of intra-abdominal pressure and the direction of venous pressures during apnea following artificial respiration (fig. 3A).

In 17 cases, spontaneous pressure changes were observed. These changes were not related to any observable changes in the small artery or the contralateral femoral artery or to intra-abdominal or respiratory movements (fig. 3B). The average pressure at which spontaneous changes were seen was found to be 30.6 mm. Hg. It was considered that the spontaneous changes in this case were evidence of independent contractions of small veins during local adjustments of blood flow and blood pressure. The rise or fall in pressure during the contractions was relatively small, with few exceptions, the average change being 4.2 mm. Hg. This may account for the infrequency with which such pressure changes are noticed when a less sensitive strain gage is used.

Pressure Changes During Occlusion of Ipsilateral Femoral Artery

In order to determine to what extent respiratory waves were influenced by arterial inflow, the femoral artery was occluded for approximately 30 seconds. There was an immediate drop in both small artery and small vein pressure. When the venous cannula was directed toward the foot, respiratory waves disappeared completely in 58 per cent of the trials. At all times, there was a marked decrease in the intensity or height of the so-called respiratory waves. The average decrease in 30 animals was 76.4 per cent (fig. 4A). However, when the venous cannula was directed toward the vena cava, the waves were never obliterated although there was an average decrease of 18.9 per cent in their height (fig. 4B). In 29 trials with the cannula directed toward the vena cava, 8 showed no change at all in respiratory waves during arterial occlusion.

Femoral vein occlusion with a bulldog clamp caused an abrupt rise in small vein pressure and abolished the waves completely.

Pressure Changes with an Open Abdomen

If the intra-abdominal pressure were the main determinant of pressure changes in the small veins, then reduction of this pressure should either change the pattern of the waves, vary their intensity, or completely obliterate them.

To reduce or remove intra-abdominal pressure, a midline incision was made in 4 animals. While this reduced the intra-abdominal pressure waves, it did not cause them to disappear and consequently the venous pressure...
PRESSURE IN SMALL VEINS

changes also continued. However, if the abdominal muscles were retracted and elevated to produce a large abdominal cavity of such size that contraction of the abdominal muscles during expiration could not produce any pressure on the viscera, both intra-abdominal and venous pressure waves disappeared completely.

Two records were obtained from each dog, 1 with the venous cannula directed toward the foot and 1 with the venous cannula directed toward the vena cava. In 8 trials, small vein pressure variations were reduced from an average height of about 1.5 to less than 0.1 mm. Hg (fig. 5).

In a few instances, a small decrease in venous pressure during inspiration replaced the previous marked increase. It is possible that the small decrease in pressure was a result of intra-thoracic pressure change that had previously been masked by the more effective intra-abdominal pressure.

Discussion

These results support the consideration that intra-abdominal pressure, exerted on the abdominal vena cava as a result of respiratory movements, is 1 of the major factors varying small vein pressure in the hindleg.

Two distinct types of pressure variations were seen in the small veins: (1) small rhythmic changes occurring at the same rate as respiration, and (2) large irregular waves. Both types of variations were seen with centrally directed cannulas and cannulas directed toward the foot. However, the irregular, spontaneous waves appeared most often when the venous cannula was directed toward the foot and when the small vein pressure was relatively high. These independent contractions may be explained on the basis of the myogenic automaticity ascribed to vascular smooth muscle cells.4

The small rhythmic changes have also been shown previously.1,3 The cyclic changes were considered to be cardiac and respiratory waves transmitted through the arterial side. Evidence for transmission through the arterial side was based upon occlusion of the ipsilat-

\[ \text{Figure 4} \]

Effect of ipsilateral femoral artery occlusion on cyclic pressure changes in a small vein. A. Venous cannula directed toward the foot. B. Venous cannula directed toward the vena cava. R = respiration; SVP = small vein pressure; IAP = intra-abdominal pressure; FAP + SAP = femoral artery pressure with small artery pressure superimposed. Pressure in mm. Hg is indicated by the numbers. Small vein pressure is written on the right-hand side of the figure. Femoral and small artery pressure is on the left-hand side of the figure. The base line represents zero for venous and arterial pressures.

\[ \text{Downloaded from http://circres.ahajournals.org/} \]
Figure 5
Effect of reduction in intra-abdominal pressure on small vein pressure. R = respiration; SVP = small vein pressure; IAP = intra-abdominal pressure; FAP + SAP = femoral artery pressure with small artery pressure superimposed. Pressure in mm. Hg is indicated by the numbers. Small vein pressure is written on the right-hand side of the figure. Femoral and small artery pressure is on the left-hand side of the figure. The base line is zero for venous and arterial pressures. The black line at the top indicates retraction of the abdominal wall.

about by femoral artery occlusion regardless of the direction of the tip of the cannula. That the waves continued to be produced during arterial occlusion when the cannula tip was directed toward the vena cava indicates that the vena cava is their point of origin. Femoral vein occlusion with a bulldog clamp abolished the waves regardless of the direction of the cannula. These results indicate that variations in small vein pressure are the result of cyclic variations in pressure in the vena cava.

The important influence of intra-abdominal pressure on small vein pressure in the hindleg was demonstrated in 2 ways. Small vein pressures were seen to rise during inspiration in some cases and in others the venous pressures dropped sharply just before inspiration and rose during a sustained expiration. This was observed to be caused by contraction and relaxation of abdominal muscles in association with respiration. Intra-abdominal pressure changes were exactly the same. Further evidence is found in the reduction in the venous waves when the abdomen is open. These observations led to the conclusion that the variations in pressure on the abdominal vena cava during respiratory movements (compression of abdominal muscles and descent of the diaphragm) are primarily responsible for the cyclic changes in small vein pressure in the hindleg of the supine, anesthetized dog.

No conclusions can be drawn from this investigation as to the relationship between intra-abdominal pressure and small vein pressure in the unanesthetized dog in a normal position.
**Summary**

Rhythmic changes in small vein pressure were shown to follow the direction of changes in intra-abdominal pressure. Pressure waves in small veins could be diminished considerably during femoral artery occlusion when the venous cannula was directed away from the vena cava. They were only slightly affected when the venous cannula was directed toward the vena cava. Small vein pressure waves were markedly decreased by opening the abdomen and reducing intra-abdominal pressure.

It is concluded that intra-abdominal pressure change is a major factor in varying small vein pressure in the hindleg of an anesthetized dog in a supine position.

**Acknowledgment**

The author wishes to thank Ruth H. Mercer, Charles Parsons, and John H. Wolf, Jr., for technical assistance.

**References**


Pressure Variations in Small Veins in the Hindleg of the Dog
MARY P. WIEDEMAN

Circ Res. 1960;8:440-445
doi: 10.1161/01.RES.8.2.440

Circulation Research is published by the American Heart Association, 7272 Greenville Avenue, Dallas, TX 75231
Copyright © 1960 American Heart Association, Inc. All rights reserved.
Print ISSN: 0009-7330. Online ISSN: 1524-4571

The online version of this article, along with updated information and services, is located on the World Wide Web at:
http://circres.ahajournals.org/content/8/2/440

Permissions: Requests for permissions to reproduce figures, tables, or portions of articles originally published in Circulation Research can be obtained via RightsLink, a service of the Copyright Clearance Center, not the Editorial Office. Once the online version of the published article for which permission is being requested is located, click Request Permissions in the middle column of the Web page under Services. Further information about this process is available in the Permissions and Rights Question and Answer document.

Reprints: Information about reprints can be found online at:
http://www.lww.com/reprints

Subscriptions: Information about subscribing to Circulation Research is online at:
http://circres.ahajournals.org/subscriptions/