# Evaluation of the Arterial Blood Pressure of Dogs by Two Noninvasive Methods

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## ABSTRACT

**The determination of the arterial blood pressure was done on 12 healthy mixed breed dogs in both the anesthetized and the conscious state, to evaluate two instruments (Doppler flow detector and infrasonde D4000), in their ability to indirectly determine arterial blood pressure.**

**The coefficients of variation were higher with indirect methods when compared with the results obtained by cannulation. These coefficients were lower with the Doppler flow detector.**

**The correlation study showed that both apparatuses were reliable in most situations. The infrasonde D4000 was more accurate than the Doppler in the conscious animals. However the results showed a lack of precision in hypertensive conscious dogs. The diastolic arterial blood pressure was particularly precise in the case of the anesthetized hypotensive dogs. Its sensitivity allowed it to register muscle movement artifacts.**

**The Doppler flow detector showed less variation and was particularly accurate in both anesthetized and conscious hypertensive dogs. Its sensitivity allowed artifact movement sounds to be detected. The Doppler should be used in quiet surroundings or earphones should be worn by the evaluator. Some form of restraint is needed with the use of both instruments. Even if the correlations with the direct arterial blood pressure values were better with the infrasonde D4000, greater variations were found in the individual readings. The Doppler instrument represents in the hands of the investigators a better instrument for routine monitoring of blood pressure in the dog.**

**Key words:** Arterial blood pressure, cannulation, Doppler flow detector, infrasonde D4000, dog.

## RÉSUMÉ

**Cette expérience consistait à évaluer la pression artérielle, de façon indirecte, chez 12 chiens croisés, à l'aide du détecteur à effet Doppler et de l'infrasonde D4000. Elle impliquait aussi la comparaison des résultats ainsi obtenus à ceux du cathétérisme artériel.**

**Les deux méthodes indirectes donnèrent des coefficients de variation plus élevés que le cathétérisme artériel. Ceux qui résultaient de l'utilisation de l'infrasonde D4000 se révélèrent aussi plus élevés que ceux qui découlaient de l'emploi du détecteur à effet Doppler.**

**L'étude des corrélations démontra une fiabilité comparable de la part des deux méthodes indirectes, dans la plupart des situations. L'infrasonde D4000 se révéla toutefois plus précise que le détecteur à effet Doppler, chez les chiens éveillés, mais elle afficha un manque de précision avec ceux chez lesquels on avait provoqué une hypertension. L'évaluation de la pression artérielle diastolique avec l'infrasonde D4000 donna des résultats très précis avec les chiens anesthésiés chez lesquels on avait provoqué une hypotension. Sa très grande sensibilité l'amena cependant à capter plusieurs artéfacts dus aux mouvements ou aux contractions musculaires.**

**Le détecteur à effet Doppler montra moins de variations; il s'avéra particulièrement précis avec les chiens en éveil ou sous anesthésie, chez lesquels on avait provoqué une hypertension. La très grande sensibilité de cet appareil lui fit toutefois capter les bruits dus aux mouvements de l'animal. Le détecteur à effet Doppler ne devrait s'utiliser que dans un endroit calme, à défaut de quoi on recommande à l'opérateur de se munir d'écouteurs. Une certaine forme de contention s'impose, quel que soit l'instrument utilisé pour la détermination indirecte de la pression artérielle.**

**Même si l'utilisation de l'infrasonde D4000 permit d'obtenir de meilleures corrélations avec les valeurs de la pression artérielle directe, elle donna lieu à de plus grandes variations, lors de lectures individuelles. Le détecteur à effet Doppler représenterait par ailleurs un instrument aussi fiable et moins dispendieux pour le monitorage routinier de la pression sanguine des chiens par les praticiens.**

**Mots clés:** pression artérielle, cathétérisme artériel, détecteur à effet Doppler, infrasonde D4000, chien.

## INTRODUCTION

Clinical evaluation of arterial blood pressure is not common in the dog. The most routine method using the stethoscope is not easily applicable to domestic animals, Korotkoff sounds being generally inaudible (1). Nevertheless, one study reports the measurement of the arterial blood pressure based on the auscultatory method (2). Invasive methods by arterial cannulation are most commonly used in research. A recent article described a practical method of measuring the arterial blood pressure by puncturing the femoral artery in the conscious dog (3).

In the dog, studies have been conducted on the indirect evaluation of

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the mean (4,5,6), systolic and diastolic (5, 7-16) arterial blood pressures. Two authors report the use of the Doppler flow detector in the cat (1) and in the dog (9). The results obtained in the former study showed a correlation within 10% with those obtained by arterial cannulation (1). In another study on dogs, a Doppler effect arterio-probe was used for the determination of the systolic and diastolic arterial blood pressures (14). Other works report the use of an oscillometric method in anesthetized dogs (4,5) with correlation coefficients better than 0.9 for all pressures (5). In a different study an electronic tensiometer was used (6). The indirect determination of the arterial blood pressure has also been evaluated in many other species (17-20).

The objective of this study was to evaluate two indirect methods, to determine the systolic (Doppler and infrasonde D4000), diastolic (infrasonde D4000) and mean (infrasonde D4000) arterial blood pressures in the anesthetized and conscious dogs. The results were compared with those of direct arterial measurements.

## MATERIALS AND METHODS

### DOGS

Twelve healthy adult mongrel dogs, six males and six females, with a mean age of three years (one to six years) and a mean weight of 22.3 kg were used.

### ARTERIAL CANNULATION

For the evaluation of the direct arterial blood pressure, the carotid and femoral arteries were cannulated. After premedication with atropine sulfate (Squibb Canada Inc., Montreal, Quebec) (0.04 mg/kg), anesthesia was induced with sodium thiamylal (Biotal: Bio-Ceutic Laboratory Inc., St. Joseph, Missouri) (30 mg/kg). The dogs were maintained on halothane (Fluothane: Ayerst Laboratories Inc., Montreal, Quebec) / oxygen.

Cannulations were performed according to the usual surgical approach (21). Sterile vinyl, 0.06″ I.D. x 0.12″ O.D., (Norton Health Care Products, Akron, Ohio) and silastic, 0.078″ I.D. x 0.125″ O.D. (Dow Corning Corp., Midland, Michigan) cannulae were inserted approximately seven centimeters into the carotid and femoral arteries. Near the skin incision which had been closed with interrupted nylon sutures, a flap of adhesive tape was placed on the cannulae and then sutured to the skin to prevent tension on the ligatures and its inadvertent removal. Both sites were bandaged and an Elizabethan collar was put on each animal. The average duration of the surgery was 45 minutes and recovery was uncomplicated in all animals. Both cannulae were flushed with a sterile solution of heparin at a concentration of 10 IU/mL every two to five hours.

### ARTERIAL BLOOD PRESSURE

The arterial blood pressure (ABP) was measured following the surgery on the anesthetized animals and twelve hours later on the conscious animals.

To record the direct arterial blood pressure (DIABP) both cannulae were connected to blood pressure transducers (Beckman Instruments Inc., Scheller Park, Illinois). Electrode clips were placed on the skin to record the electrocardiogram. All leads were connected to a polygraph (Beckman R511A; Beckman Instruments Inc., Scheller Park, Illinois). Monitoring was done during both experiments. The systolic (SABP) and diastolic (DABP) blood pressures were recorded; the mean arterial blood pressure (MABP) was estimated by the following formula (22):

$$MABP = DABP + \frac{(SABP - DABP)}{3}$$

To record the indirect arterial blood pressure (INABP) the ultrasonic Doppler (Parks Electronics Laboratory, Beaverton, Oregon) flow detector probe was placed on the left ulnar artery. The area was clipped, ultrasound transmission gel (Aquasonic 100: Parker Laboratories Inc., Orange, New Jersey) applied to the skin and the probe attached with adhesive tape. A pressure cuff (Tycos precalibrated infant cuff: Parks Electronics Laboratory, Beaverton, Oregon) of adequate width, approximately 40% the circumference of the leg, was placed just below the elbow. Only the SABP was evaluated with the Doppler. The blood pressure was recorded when the first arterial sound was heard following the presystolic sounds. The pressure cuff with probe (Neonate cuff: Sphygmetrics Inc., Woodland Hills, California) from the infrasonde D4000 (Sphygmetrics Inc., Woodland Hills, California) was set on the tibial artery after clipping the skin area, no gel being needed. The SABP, DABP and MABP were evaluated with this instrument. All recordings were taken simultaneously.

To evaluate these methods in simulated pathological conditions, sodium nitroprusside (Nipride: Hoffman-LaRoche Ltd, Vaudreuil, Quebec) was administered intravennously at a dose rate of 6 $\mu$g/kg/min by infusion pump to produce hypotension and phenylephrine hydrochloride (Neo-synephrine hydrochloride: Winthrop Laboratories, Division of Sterling Drugs, Aurora, Ontario) was given at a dose of 0.035 mg/kg in a single rapid injection to produce hypertension. Three measurements were taken in nontreated and treated animals, in both the anesthetized and conscious states.

## RESULTS

In the anesthetized dogs, the average arterial blood pressures (SABP/DABP and MABP) were 120/93 and 102 mm Hg as observed by cannulation of the carotid artery and 132/90 and 104 mm Hg for the femoral artery. Using the infrasonde D4000, values were 131/97 and 109 mm Hg. Using the Doppler flow detector the average SABP was 127 mm Hg (Table I).

In the conscious animals, the results obtained with arterial cannulation were: carotid, 141/99 and 113 mm Hg, and femoral, 154/96 and 115 mm Hg. The indirect evaluations were: 152/104 and 120 mmHg for the infrasonde D4000 and 145 mm Hg for the Doppler (Table I).

In the anesthetized hypotensive dogs, the average carotid and femoral arterial blood pressures were 104/76 and 86 mm Hg and 107/75 and 85 mm Hg respectively. The results were 104/79 and 87 mm Hg using the infrasonde D4000 and 104 mm Hg with the Doppler (Table II).

In the conscious hypotensive animals, the results were: carotid, 127/92

**TABLE I. Evaluation of the Arterial Blood Pressure (mm Hg) of Anesthetized and Conscious Dogs**

| | Anesthetized Dogs[a] | | | Conscious Dogs[a] | | |
|---|---|---|---|---|---|---|
| | SABP[b] | DABP[c] | MABP[d] | SABP | DABP | MABP |
| Carotid cannulation | 120 ± 17.9[e] (14.9%)[f] | 93 ± 19.1 (20.5%) | 102 ± 18.1 (17.7%) | 141 ± 22.8 (16.2%) | 99 ± 14.7 (14.8%) | 113 ± 16.1 (14.2%) |
| Femoral cannulation | 132 ± 21.8 (16.5%) | 90 ± 19.2 (21.3%) | 104 ± 18.4 (17.7%) | 154 ± 30.5 (19.8%) | 96 ± 11.9 (12.4%) | 115 ± 16.2 (14.1%) |
| Doppler flow detector | 127 ± 21.9 (17.3%) | — | — | 145 ± 22.5 (15.4%) | — | — |
| Infrasonde D4000 | 131 ± 23.7 (18.1%) | 97 ± 23.3 (23.9%) | 109 ± 22.4 (20.5%) | 152 ± 38.4 (25.3%) | 104 ± 22.8 (21.9%) | 120 ± 25.2 (21.0%) |

[a]N = 12
[b]Systolic arterial blood pressure mm Hg
[c]Diastolic arterial blood pressure mm Hg
[d]Mean arterial blood pressure mm Hg
[e]$\bar{x}$ ± SD
[f]( ) Coefficient of variation

**TABLE II. Evaluation of the Arterial Blood Pressure (mm Hg) of Anesthetized and Conscious Dogs Treated with Sodium Nitroprusside**

| | Anesthetized Dogs[a] | | | Conscious Dogs[a] | | |
|---|---|---|---|---|---|---|
| | SABP[b] | DABP[c] | MABP[d] | SABP | DABP | MABP |
| Carotid cannulation | 104 ± 22.9[e] (21.9%)[f] | 76 ± 25.1 (33.0%) | 86 ± 23.9 (27.8%) | 127 ± 17.4 (13.7%) | 92 ± 15.4 (16.8%) | 104 ± 14.1 (13.6%) |
| Femoral cannulation | 107 ± 28.5 (26.5%) | 75 ± 24.4 (32.7%) | 85 ± 24.4 (28.7%) | 128 ± 22.9 (17.8%) | 88 ± 11.1 (12.6%) | 101 ± 12.9 (12.8%) |
| Doppler flow detector | 104 ± 25.9 (24.9%) | — | — | 131 ± 23.1 (17.6%) | — | — |
| Infrasonde D4000 | 104 ± 26.8 (25.7%) | 79 ± 23.2 (29.3%) | 87 ± 23.2 (26.7%) | 129 ± 30.1 (23.3%) | 90 ± 22.8 (25.3%) | 103 ± 22.1 (21.5%) |

[a]N = 12
[b]Systolic arterial blood pressure mm Hg
[c]Diastolic arterial blood pressure mm Hg
[d]Mean arterial blood pressure mm Hg
[e]$\bar{x}$ ± SD
[f]( ) Coefficient of variation

and 104 mm Hg, and femoral, 128/88 and 101 mm Hg. The results were 129/90 and 103 mm Hg with the infrasonde D4000 and the SABP was 131 mm Hg using the Doppler (Table II).

In the anesthetized hypertensive dogs, the average arterial blood pressures were 180/136 and 152 mm Hg for the carotid artery and 192/139 and 156 mm Hg for the femoral artery. The values were 165/123 and 136 mm Hg with the infrasonde D4000 and the average SABP was 176 mm Hg using the Doppler (Table III).

In the conscious hypertensive animals, the values were: carotid, 190/128 and 149 mm Hg, and femoral, 197/124 and 149 mm Hg. The results were 180/135 and 150 mm Hg with the infrasonde D4000. The SABP was 180 mm Hg using the Doppler (Table III).

The systolic arterial blood pressures of anesthetized and conscious dogs, as measured by carotid cannulation, femoral cannulation, Doppler flow detector and infrasonde D4000, are shown in Figs. 1 and 2.

Table IV shows the heart rate values of dogs in either a hypotensive or hypertensive state.

Table V illustrates the correlations between the arterial blood pressure obtained by noninvasive techniques and by cannulation of the carotid or femoral artery. These coefficients ranged from 0.32 to 0.86.

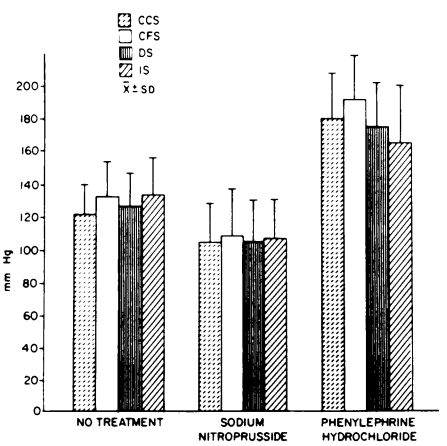


**Fig. 1. Evaluation of the systolic arterial blood pressure (SABP) of anesthetized dogs by carotid cannulation (CCS), femoral cannulation (CFS), Doppler flow detector (DS) and infrasonde D4000 (IS).**

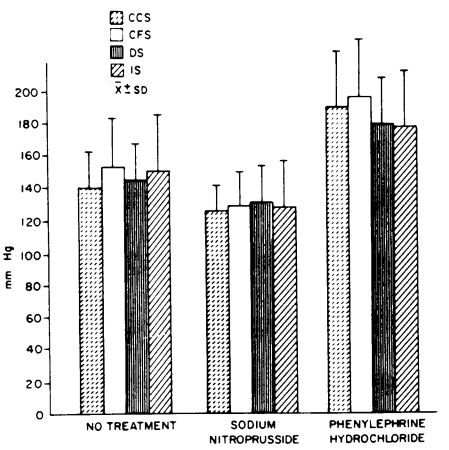


**Fig. 2. Evaluation of the systolic arterial blood pressure (SABP) of conscious dogs, by carotid cannulation (CCS), femoral cannulation (CFS), Doppler flow detector (DS) and infrasonde D4000 (IS).**

**TABLE III. Evaluation of the Arterial Blood Pressure (mm Hg) of Anesthetized and Conscious Dogs Treated with Phenylephrine Hydrochloride**

| | Anesthetized Dogs[a] | | | Conscious Dogs[a] | | |
|---|---|---|---|---|---|---|
| | SABP[b] | DABP[c] | MABP[d] | SABP | DABP | MABP |
| Carotid cannulation | 180 ± 30.9[e] (17.2%)[f] | 136 ± 20.3 (14.9%) | 152 ± 22.7 (15.0%) | 190 ± 34.9 (18.3%) | 128 ± 23.3 (18.3%) | 149 ± 26.0 (17.5%) |
| Femoral cannulation | 192 ± 28.3 (14.8%) | 139 ± 24.2 (17.4%) | 156 ± 22.8 (14.6%) | 197 ± 37.0 (18.8%) | 124 ± 23.3 (18.6%) | 149 ± 25.2 (17.0%) |
| Doppler flow detector | 176 ± 28.0 (15.9%) | — | — | 180 ± 30.2 (16.7%) | — | — |
| Infrasonde D4000 | 165 ± 37.7 (22.8%) | 123 ± 33.9 (27.6%) | 136 ± 33.1 (24.2%) | 180 ± 34.1 (18.9%) | 135 ± 30.2 (22.4%) | 150 ± 29.7 (19.8%) |

[a]N = 12
[b]Systolic arterial blood pressure mm Hg
[c]Diastolic arterial blood pressure mm Hg
[d]Mean arterial blood pressure mm Hg
[e]$\bar{x}$ ± SD
[f]( ) Coefficient of variation

**TABLE IV. Evaluation of the Heart Rate in Anesthetized and Conscious Dogs (beats/min)**

| | Anesthetized Dogs[a] | Conscious Dogs[a] |
|---|---|---|
| No treatment | 123 ± 16[b] (13.0%)[c] | 94 ± 19 (20.2%) |
| Na nitroprusside | 125 ± 24 (19.2%) | 117 ± 32 (27.4%) |
| Phenylephrine hydrochloride | 98 ± 24 (24.5%) | 58 ± 17 (29.3%) |

[a]N = 12
[b]$\bar{x}$ ± SD
[c]Coefficient of variation

**TABLE V. Correlation Coefficients Between the Doppler Flow Detector and the Infrasonde D4000 with the Arterial Blood Pressures Taken in the Anesthetized and Conscious Dogs**

| | AN | AHO | AHY | CN | CHO | CHY |
|---|---|---|---|---|---|---|
| DS: CCS | 0.51 | 0.78 | 0.81 | 0.64 | 0.69 | 0.81 |
| IS: CCS | 0.62 | 0.81 | 0.78 | 0.81 | 0.66 | 0.60 |
| DS: FCS | 0.61 | 0.75 | 0.80 | 0.64 | 0.52 | 0.76 |
| IS: FCS | 0.71 | 0.76 | 0.82 | 0.86 | 0.76 | 0.32 |
| ID: CCD | 0.56 | 0.85 | 0.57 | 0.61 | 0.66 | 0.63 |
| ID: FCD | 0.51 | 0.81 | 0.56 | 0.51 | 0.53 | 0.68 |

P = ⩽ 0.05
N = 36
AN = Anesthetized normal dogs
AHO = Anethetized hypotensive dogs
AHY = Anesthetized hypertensive dogs
CN = Conscious normal dogs
CHO = Conscious hypotensive dogs
CHY = Conscious hypertensive dogs
DS = Doppler SABP
CCS = Carotid cannulation SABP
IS = Infrasonde D4000 SABP
FCS = Femoral cannulation SABP
ID = Infrasonde D4000 DABP
CCD = Carotid cannulation DABP
FCD = Femoral cannulation DABP

## DISCUSSION

The measurement of arterial blood pressure of dogs has been the subject of many studies in the last decade (4,6,7,8,11,12,14,15,16). These have involved the use of direct or indirect methods, but few report an exhaustive correlation study (4,5). Thus, it has been difficult to interpret the results obtained with indirect methods which are still not yet applied routinely.

The use of the Doppler did not present any problem in the anesthetized dogs. Thus we feel that the cuff width should be approximately 40% the circumference of the leg. As previously described (1,4), our observations have shown that when the cuff is too wide, readings are abnormally low and when it is too small, they are abnormally high. Once the cuff was positioned many readings could be taken without any problems or need to reposition the probe. However, in the induced state of hypertension, the Doppler sounds were lost when the ABP was higher than 200 mm Hg.

The infrasonde D4000 is a highly sensitive digital instrument, which may record extraneous muscle movements. The probe and cuff had to be repositioned often during each evaluation, making the use of this apparatus time consuming. Readings fluctuated greatly in spite of constant direct arterial blood pressure measurements.

In both anesthetized and conscious nontreated dogs, there was no statistical difference between direct and indirect evaluation of the SABP, DABP and the MABP (Table I). However the coefficients of variation ranged from 12.4 to 25.3%, with the higher percentages being found using the infrasonde D4000.

During induced hypotension, the SABP was consistent regardless of the method of evaluation. However greater variations were observed in anesthetized dogs (Table II). The coefficients of variation ranged from 12.6 to 33%, the higher percentages being found in the anesthetized animals and for the DABP taken by cannulation. The coefficients of variation with the Doppler ranged from 17.6 to 24.9% and were quite similar to those obtained with the infrasonde D4000, which varied from 21.5 to 29.3% (Table II).

During induced hypertension, there was also no statistical difference between the indirect and direct determinations (Table III). The coefficients of variation ranged from 14.6 to 27.6%, the higher percentages being found with the use of the infrasonde D4000. With both cannulation and the Doppler, these coefficients varied from 14.6 to 18.8%, while they ranged from 18.9 to 27.6% with the use of the infrasonde D4000 (Table III).

Generally, the coefficients of variation were lower in all results obtained by the direct method except in anesthetized hypotensive dogs. Greater

variability was found in the indirect evaluations. Even though the coefficients of variation were slightly lower with the Doppler, both indirect systems compared advantageously.

A correlation study of both indirect methods and arterial cannulation showed consistent measurement of the SABP in anesthetized dogs.

In the nontreated conscious animals, the infrasonde D4000 showed a closer correlation with the direct SABP. On the other hand, the Doppler detected hypertension more reliably. The diastolic blood pressure measured by the infrasonde D4000 was particularly precise in the case of anesthetized hypotensive dogs. In all other situations the coefficients ranged from 0.51 to 0.68 and were in accordance with the general results of the experiment (Table V).

## CONCLUSION

The Doppler system is a reliable and nonexpensive indirect SABP evaluation method. The price of the Doppler ($600) makes it accessible for most practices.

The infrasonde D4000 is also a reliable instrument. However, being a much more expensive apparatus ($5000), it may be out of reach for many veterinary private practitioners.

As these two apparatuses are very sensitive, artifacts occurred whenever the dogs moved. Thus, some form of restraint is needed. In addition, a quiet surrounding helps in monitoring the Doppler. If this cannot be achieved, the evaluator should wear earphones.

On a cost/reliability ratio, the Doppler represents a better instrument for routine monitoring and as a diagnostic aid in private practice.

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