

## Introduction

Cardiac output (CO) is a measure of the quantity of blood pumped by the heart each minute and is the product of stroke volume (ie. volume of blood ejected with each heart beat) and heart rate. Whilst CO may be determined using ultrasonic, Fick or Indirect Fick Principles, the thermodilution technique is the most commonly used in small animals.

The thermodilution technique usually involves injecting isotonic saline (0.9%), of a known temperature, into the circulation and measuring a change in blood temperature downstream (arterial circulation) of the injectate. An important factor in using this technique is to ensure that the temperature and volume of the saline injectate are measured accurately prior to injection. A fast responding thermistor probe is also necessary for measuring the temperature change in small animals.

Advantages in using the thermodilution technique are:

1. Small volumes of saline used in each determination are innocuous, allowing repeated determinations to be made.
2. Recirculation is negligible.

## Cardiac Output Pod and Cardiac Output Accessory Kit

ADInstruments have configured a Pod and Accessory Kit to measure CO in small animals. The following items are supplied with the Pod and Accessory Kit making preparation of the experimental animal and determination of cardiac output easier.

- Six catheters of PE10 polyethylene tubing (20 cm) with needle hubs (suitable for mice, rat, guinea pigs and rabbits)
- Four three-way taps
- Two Touhy Borst Adapters
- Glass microlitre syringe and repeater dispenser

## Preparation of catheters and temperature probe

### Jugular vein catheter

- Attach a three-way tap to the needle hub of a catheter.
- Attach a 5ml syringe filled with heparinized-saline to the tap and fill the catheter
- Turn the tap to the off position so that no fluid can enter or leave the catheter

### Carotid catheter and thermistor probe

- Attach a three-way tap to the needle hub of a catheter.
- Attach a 5ml syringe filled with heparinized-saline to the tap and fill the catheter.
- Carefully remove the syringe and tap so as to ensure the saline remains in the catheter and insert the Touhy Borst Adapter to the needle hub.
- Insert the thermocouple probe through the Touhy Borst Adapter and feed it through the catheter until the end of the probe is in the tip of the catheter.
- Tighten the adapter to secure the probe in the catheter and to prevent blood entering the cannula after insertion into the artery.

## Surgical preparation

The following surgical and experimental procedures are suitable for use in small animals such as mice, rats, guinea pigs and rabbits.

The anaesthetized animal should be placed on a heated table/mat during the surgery and throughout the experimental procedure to ensure a stable body temperature. A stable body temperature will ensure anaesthesia is maintained as well as contribute to accurate determination of CO. The animal body temperature should be continuously monitored and ideally a temperature feedback system controlling the heating table/mat may be used, however this is not essential.

## Anaesthesia

General notes on anaesthesia and surgery:

- The animal should be anaesthetized appropriately before beginning any surgery with the level of anaesthesia monitored and maintained throughout the surgery and experimental procedure.
- With the animal on its back and using a scalpel, an incision is made from the chin to the sternum. The skin either side of the incision is freed using blunt dissection.

## Cannulation of jugular vein

- Locate the jugular vein as it passes under the superficial pectoral muscle (Figure 1).

NOTE: Veins contain smooth muscle and therefore when excessively manipulated will constrict. Gentle massaging of the neck and face can promote venous filling.

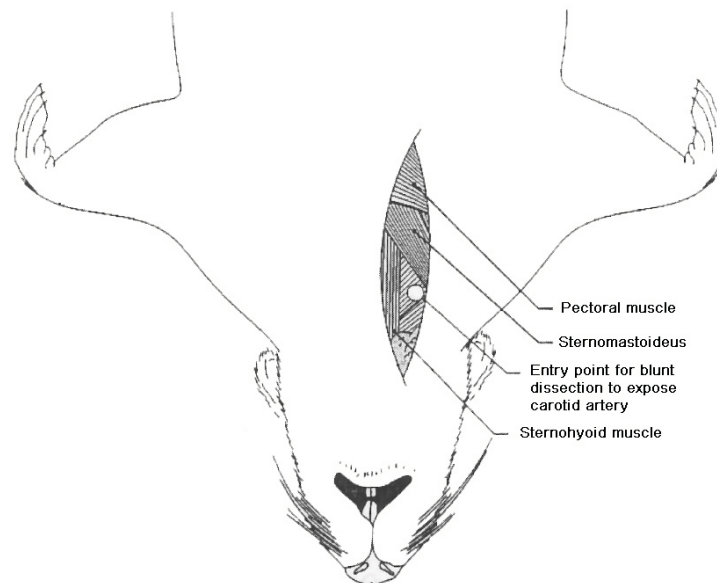


Figure 1: Incision through the neck to expose underlying muscle layers

- Clear the fat and connective tissue from a segment of the vein.
- Place one cranial and two caudal ligatures (2-3 or 4-0 silk) under the vessel.

- Tie the cranial ligature and secure with a double knot.
- Using small, sharp dissecting scissors make an incision approximately 1/3 of the way through the vessel producing a V-shaped flap with the 'V' pointing towards the heart (Figure 2).
- With the cranial tie held taught and using the tip of curved forceps to open the incision, insert the catheter tip into the vessel.
- Once in the vessel, apply a small amount of negative pressure using a syringe connected to the tap. If the catheter is in the vessel, venous blood should appear in the catheter.
- Flush any blood from the catheter and secure the two caudal ligatures around the catheter

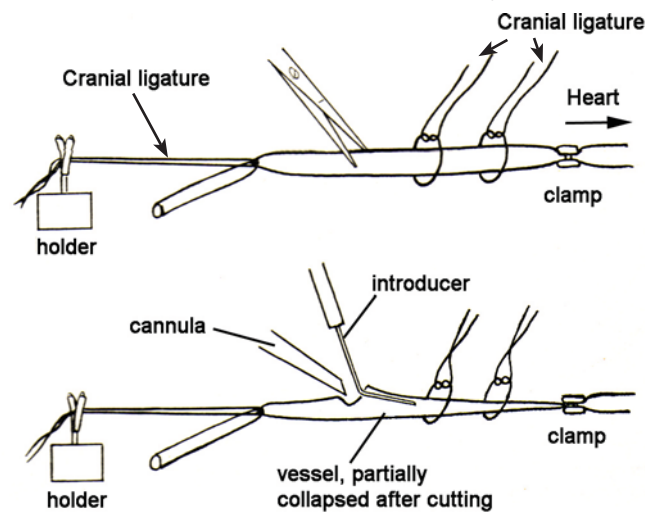


Figure 2: Vascular cannulation

## Cannulation of the common carotid artery

- Identify the trachea. The carotid artery lies deep in the strap muscles of the neck lateral and close to the trachea.
- Use blunt dissection to clear a path through the muscle to the carotid artery.
- The vagus nerve is attached to the carotid artery by connective tissue and must be freed using blunt dissection.
- Once the artery is cleared of the nerve and connective tissue pass three silk ligatures one proximal (towards the head) and 2 distal (toward the heart).
- Tie off the carotid artery as far proximally as possible but do not cut the ends of the silk (these are used to add tension to the vessel whilst inserting the cannula (Figure 2)).
- Loose knots should be made around the artery using the remaining two ligatures.
- Blood flow from the heart should be stopped by placing a "bull-dog" clamp on the vessel between the two loose ligatures.
- Whilst applying counter-traction on the artery with the proximal ligature, a V-shaped incision 1/3 of the artery's circumference is made.
- With some traction on the vessel insert the cannula containing the thermocouple probe and heparinized-saline (1-1.5 cm) into the vessel with or without the aid of curved forceps (care should be taken not to squeeze the catheter and probe with the forceps).

- Securely tie the proximal ligature around the artery and catheter prior to removing the “bull-dog” clamp (ensure that the knot is tight enough to hold the catheter in place but loose enough to allow the catheter to be inserted further into the vessel).
- Feed the cannula towards the heart.
- To ensure the cannula is secured, double knot both ligatures around the vessel and catheter (Figure 3, note only one tie is shown in the image over).
- Once secured, loosen the Touhy Borst Adapter and push the thermistor past the tip of the catheter (approx. 5 mm)
- Figure 4 represents the final arrangement of the injectate and thermistor probe catheters.

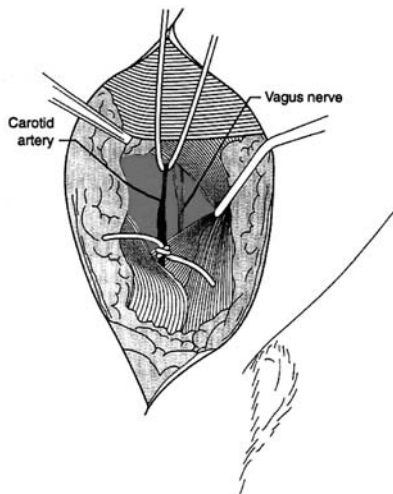


Figure 3(a): Separation of carotid artery from vagus nerve and connective tissue. Proximal ligature knotted

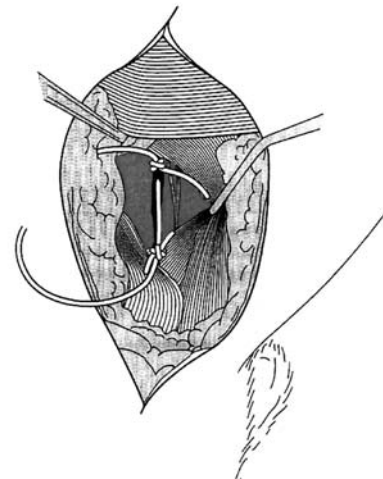


Figure 3(b): Distal ligature securing the catheter to the artery

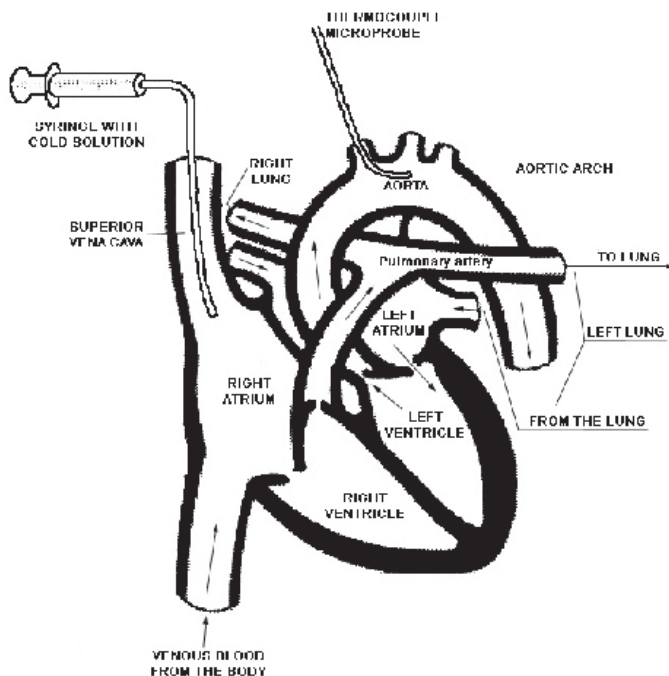


Figure 4: Schematic representation of the injectate catheter and thermocouple probe

## Experimental parameters

The following table is a summary from the literature of approximate values for various physiological parameters in small mammals. The table values are meant only as a guide to help in determining injectate volumes and temperatures for measuring cardiac output using thermodilution in a particular species. For specific information on a particular species or specific strain we strongly recommend consulting the published literature.

Table 1: Physiological and experimental conditions for measuring CO in small mammals

Species	Body temperature (°C)	Heart rate (bpm)	Injectate temperature (°C)	Injectate volume (µl)
Mouse	36.5 to 38	300 to 650	15 to 25	15 to 25
Rat	36 to 37.5	330 to 480	15 to 25	120 to 150
Guinea pig	37.5 to 39.0	240 to 300	15 to 25	100 to 120
Rabbit	38 to 40	120 to 300	15 to 25	200 to 250

The material presented here is believed accurate at the time of writing and is only intended as an introduction to cardiac output monitoring techniques. ADInstruments assume no liability for the use or misuse of the preceding information.