A ONE-WAY-VALVE CHEST WOUND DRESSING: EVALUATION IN A CANINE MODEL OF OPEN CHEST WOUNDS

FASTBREATHE THORACIC SEAL (FTS)

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ABSTRACT

Objective: To test a chest wound dressing incorporating a low profile one-way valve dressing (OWVD) designed for use in prehospital treatment of pneumothorax in penetrating chest trauma by comparing it to conventional petrolatum impregnated gauze dressings (PGD). Design: six dogs were used to develop an anesthetized breathing model using ketamine (40 mg/kg), midazolam (200 ug/kg), and fentanyl (10 ug/kg) maintained with an infusion of 600 ug/kg/min, 5 ug/kg/min, and .5 ug/kg/min respectively. Four dogs served as a control group evaluation this model on and off the ventilator. Eight dogs with bilateral standardized chest wounds were randomized into two groups in a crossover design study. One group tested the PGD first and then the OWVD, both with and without positive pressure ventilation (PPV). The second group tested the OWVD then the PGD. Dogs were stabilized between tests of each device. Respiratory rate, heart rate, arterial blood gases and hemoglobin oxygen saturation (qualitative) were monitored. Results: The control group showed stable vital signs throughout testing. Animals on PPV maintained stable vital signs regardless of the dressing applied. Dogs without PPV were unable to survive a 15 minute period with the PGD, whereas dogs with the OWVD were able to adequately maintain vital signs. The OWVD prevented collapse in 7 of 8 tests while the PGD prevented collapse in none of 8 tests in dogs without PPV. A probability of $p = 0.0007$ was found when Fisher's exact test was applied to this combined data. Conclusion: The OWVD out-performed the conventional PGD in preventing severe decompensation in dogs with bilateral open chest wounds without PPV.

INTRODUCTION

The purpose of our study is to test a chest wound dressing incorporating a one-way valve and compare it to the traditional occlusive petrolatum gauze dressing used in pre-hospital care of penetrating chest wounds. A simple, disposable chest wound dressing incorporating a light weight, low profile, and low resistance silicone-leaflet one-way valve has recently become available.

Penetrating chest wounds are increasing at an astronomical rate[1]. These patients pose difficult pre-hospital problems. The patient is usually unstable and in need of immediate transport. The traditional sterile occlusive dressing taped to the skin on three sides is difficult and time consuming to apply under field conditions. Frequently there are multiple wounds to manage, as in through and through gunshot wounds.

The open, “sucking” chest wound allows air to enter the chest and separate the visceral and parietal pleural surfaces, breaking the thin fluid layer between the lung and chest wall. The elastic tissues of the lung normally produce a physiologic negative pressure differential between the potential intrapleural space and the outside of 4 – 12 cm water[2]. The elastic recoil of the lung causes it to pull away from the chest wall and air is drawn into the chest through the wound. Unassisted ventilation becomes impossible when respiratory movements of the chest wall and diaphragms result only in air movement through the wound instead of through oropharynx. If the wound is small, the patient can compensate with exaggerated chest wall and diaphragmatic movement because the wound offers more resistance to air flow than the bronchial tree and airway. It has been estimated that wound two-thirds the diameter of the trachea offers less resistance than the normal

airway[3]. When positive pressures is used, the lung can expand if air moves out of the wound or if the pressure of ventilation is high enough to compress the air within the pleural space. Tension pneumothorax can develop if there is a lung injury with an air leak into the pleural space and the wound is occluded or functions as a one-way valve allowing air into but not out of the chest. Tension pneumothorax can develop with or without positive pressure ventilation. A small pneumothorax can quickly become a tension pneumothorax when positive pressure ventilation is added to an occluded wound with underlying lung injury and air leak.

An ideal dressing should possess certain qualities. It should be simple, quick, easily applied, and non-invasive. It should have a low profile and be sturdy enough to be used on the posterior thorax of a supine patient. Most importantly it should prevent influx of air on spontaneous inspiration through the wound and allow escape of air from the potential pleural space during any escape of air from the potential pleural space during any phase of respiration or assisted ventilation to avoid a tension pneumothorax.

A disposable chest wound dressing incorporating a light weight, low profile and low resistance silicone leaf one-way valve has become available. This chest wound dressing appears to satisfy the qualities discussed above. From experience at our institution, conventional occlusive petrolatum-gauze dressings are frequently unreliable in preventing influx and allowing egress of air from a chest wound. It is virtually impossible for providers to place these dressings while wearing latex gloves and to get tape to stick to a bloody surface. They are time consuming to place at a time when other procedures also need to be performed. This study was designed to determine if this device in a laboratory model of open chest wounds.

MATERIALS AND METHODS

Approval of the institutional animal use review committee was obtained for this study. A total of 18 mature mongrel dogs weight 10 to 25 kg were used. Six dogs were used to develop an anesthesia regimen that reliably resulted in a fully anesthetized but breathing model. The regimen included an IV anesthetizing dose of midazolam HCL, 200 ug/kg, alfentanil citrate, 10 ug/kg, and ketamine HCL, 40 mg/kg. Anesthesia was maintained with an infusion pump delivering a solution of midazolam HCL, 5 ug/kg/min, alfentanyl citrate 0.4 ug/kg/min, and ketamine HCL, 600 ug/kg/min. If a dog made spontaneous non-ventilatory movements, additional IV boluses of midazolam HCL, 100 ug/kg were given during the experimental period.

All dogs were monitored as follows: Hemoglobin O2 saturation (SaO2) using a Oxisensor adult digit oxygen transducer wrapped around the tongue; Heart rate (HR) using ECG lead II; Central venous pressure (CVP) and mean arterial pressure (MAP) monitored via catheters placed percutaneously into an external jugular vein and femoral artery; Core temperature (CT) using an esophageal probe. The SaO2, HR, MAP and CT were displayed and recorded using a Hewlett-Packard Merlin monitoring system and pressure transducer. CVP was measured using a saline manometer in mmH2O = 9.807 Pa). Arterial blood gases were measured using a Corning Model 168 blood gas analyzer.

All dogs had their chests, neck, and groins shaved after induction of anesthesia. All dogs were orotracheally intubated using a cuffed 8.5 mm I.D. tube. Positive pressure ventilation with room air with a Bennett MA-1 respirator at ten breaths per minute with a tidal volume taken from the Kleinman ventilation graph plus 50 cc to compensate for dead-space in the

apparatus. Peak flow was set at 30 L/min. Sigh ventilations of 1000 cc were administered as needed to return the animal to stable state between experimental periods. An infra red heating lamp was placed over the torso to maintain body temperature at 37.0 to 38.5 C.

Dogs that were to receive open chest wounds had plastic sleeves with an internal diameter of 6 mm placed bilaterally in the 6th intercostal space at the anterior axillary line using a guidewire technique. The sleeves were curved to conform to the chest wall and were 7 cm in length with multiple side holes. They were sutured flush to the skin. This ended the period of preparation.

Twelve dogs were randomly assigned to one of three groups. Group 3 consisted of four dogs and served as in anesthesia control group. They were monitored at five minute internals for four 20 minute periods, the first and third in which they were breathing spontaneously while the second and fourth were respirator dependant. Groups 1 and 2 were the experimental groups. These dogs had bilateral chest holes placed followed by the application of chest suction to the sleeves at 200 mm of H2O vacuum while on the respirator allowing them to recover from the brief collapse of the lungs cased by the procedure. After a fifteen minute period of stabilization the lungs were allowed to collapse by removing the respirator and chest wall suction for one minute. Either the conventional gauze dressing of the experimental one-way valve dressing was then applied as shown in our experimental algorhytm (Figure 1). During this time the dressings were tested with fifteen minute trials on and off the respirator respectively. The dressing was then removed and the dogs were placed back on the respirator and chest wall suction for a fifteen minute period of restabilization. Lungs were collapsed again by removal of the respirator and chest wall suction for

one minute. The opposite dressing as used before was then applied and tested with fifteen minute trials on and then off the respirator. Following this the dogs were euthanized with an IV KCL bolus.

The petroleum gauze (PG) dressings were placed over the chest holes, molded to the chest and taped using two inch strips of waterproof adhesive tape. The one-way valve (OWV) dressings were placed over the chest holed and pasted to the skin with silicone sealant. If a dog became agonal with a SaO2 of less than 50 percent while off the respirator, the respirator was re-applied and sigh ventilations were used to re-expand the lungs. When a dog was unable to sustain itself during the fifteen minute trial without respirator support, multiple attempts were made to re-stabilize the dog and try again until the fifteen minute trial had elapsed.

One dog randomly assigned to Group 2 was found to have evidence of pneumonia with copious purulent drainage from the trachea and severe hypotension / hypoxia throughout. Another dog was subsequently added to Group 2 and the dog with pneumonia eliminated from the study. One other dog had black pigmentation of the tongue which interfered with SaO2 measurements. In this instance, the dog's vital signs and ECG were used to confirm an agonal condition.

RESULTS

Anesthesia control Group 3 revealed no significant deterioration of vital signs or blood gases over the experimental period. See Figure 2.

We then compared data from Groups 1 and 2 which showed that vital signs of dogs testing the gauze and one-way valve dressings were very stable and similar <u>while the dogs were being ventilated.</u>

Data from Group 1A and 2B which represents gauze dressing results was compared with data from Groups 2A and 1B which represents the valve dressing results. Figure 3 graphs the gauze results compared to valve results. Both dressings appeared perform similar based on vital signs. We then looked at whether it made any difference if the dressing was tested early (Groups 1A and 2A) prior to testing the opposite dressing, or late (groups 2A and 2B) after previously testing the opposite dressing. Figure 4 shows these vitals also little variation.

This finding allowed the combining of data from groups 1 and 2 to determine the significance of differences in response to either of the two variable dressings. Data showed that both dressings performed equal when dogs were supported by the respirator.

There was a very significant difference between the two dressings when the dogs were not supported with a respirator. The one-way valve dressing protected the dogs from severe collapse 7 out of 8 times. Figure 5 shows mean arterial blood pressure of the dogs testing the valve dressing after respirator support has been removed. Mean pressure remains stable. Figure 6 show the heart rate of this same group which also remains stable. Only one dog required rescue support by being placed back on the respirator for three minutes as shown in Figure 7. In contrast, dogs testing the gauze dressings were very unstable and none of them survived the 15 minute trial without rescue and ventilatory support. These vital signs were very unstable, and much of the time actually represents time on a respirator during rescue periods. Figure 10 shows these rescue periods. Figure 10 shows these rescue periods which all eight dogs testing the gauze dressing required. Multiple attempts for rescue were performed in most dogs.

ANALYSIS

Descriptive statistical techniques were used to determine the stability of the anesthesia control group. Descriptive statistical techniques were also used to determine the effect of the timing of experimental variable periods in group 1 and 2. Fisher's Exact Test of probability was used to determine if there was a significant difference in performance of the two dressings with and without respirator support giving a p – value of 0.0007. See Figure 11.

DISCUSSION

Bench research of pneumothorax and tension pneumothorax is severely limited by the anatomic characteristics of most laboratory animals. The dog, pig, cat, rabbit, and rat all have an incomplete mediastinum[4]. Sheep and goats do have a complete mediastinum 5 but are relatively unavailable in the laboratory setting. Since the dog has an oxyhemoglobin dissociation curve almost identical to that of humans, very similar blood viscosity properties and red blood cell size and configuration, we elected to develop our model using dogs[6]. By placing a hole on both sides of the chest we created a severe, constant model of open chest wound simulating bilateral chest wounds in humans.

The conventional method of pre-hospital treatment of penetrating chest wounds is to apply an occlusive dressing. Although they make intuitive sense, there is no recent experimental data supporting the use of occlusive dressings taped to the chest. Gauze dressings used in our studies consisted of 4 x 4 inch petrolatum impregnated gauze covered with 4 x 4 inch gauze bandages which were taped to the skin on all four edges. This is similar to a wound dressing on the posterior thorax of a supine patient. Dressings applied were not air-tight.

LIMITATIONS

Limitations include relatively small numbers used and the assumption that our crossover design was valid to make the most of our small numbers. The incomplete mediastinum of a dog was also used.

CONCLUSION

An open chest wound dressing with a one-way valve improves pulmonary functioning in the absence of positive pressure ventilation, and functions as well as the standard occlusive gauze dressing when positive pressure ventilation is applied.

REFERENCES:

1.

2. Sabiston: Textbook of Surgery, 14th Edition, p 1719.

3.

4.

5.

6.

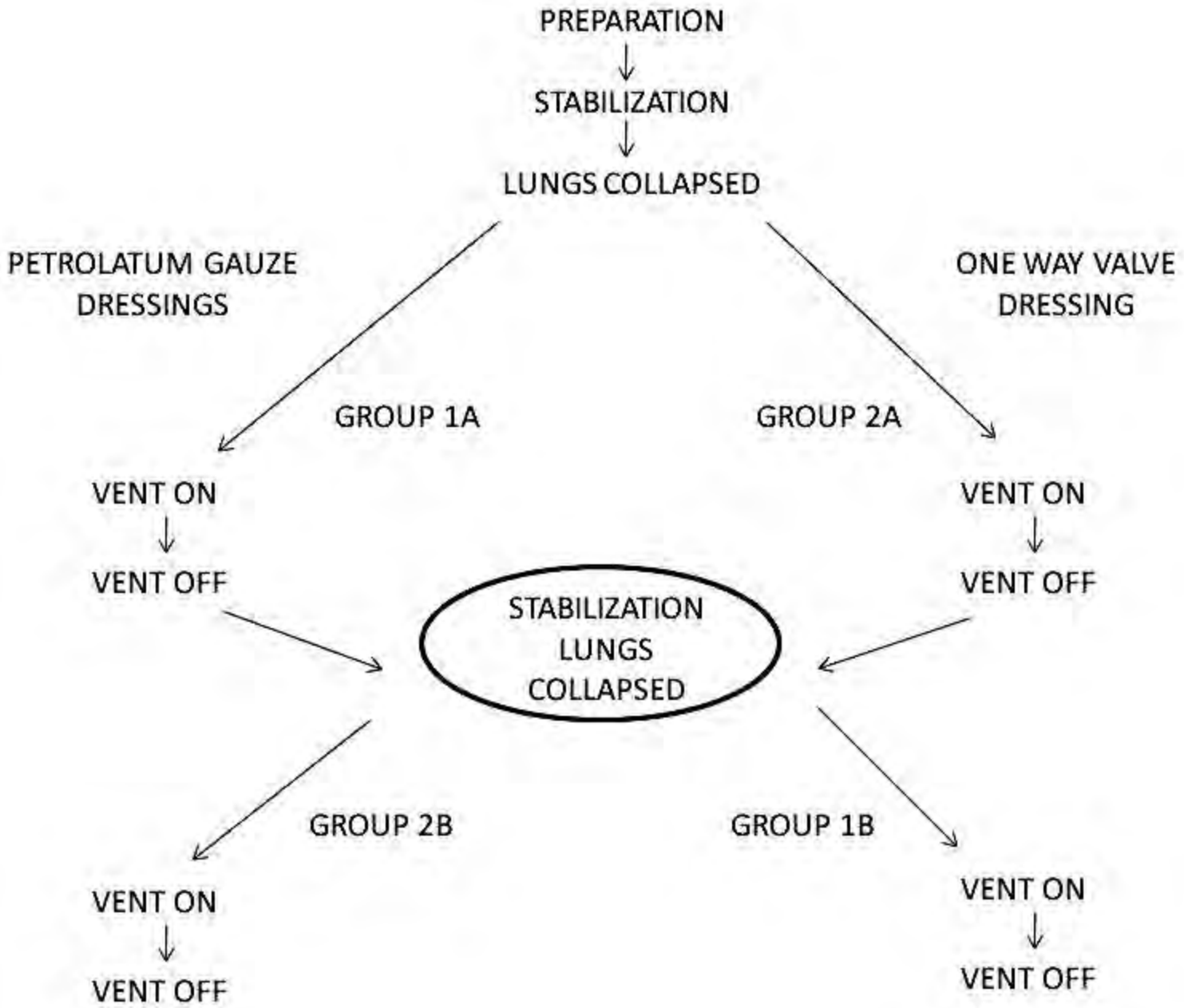

PREPARATION
STABILIZATION
LUNGS COLLAPSED
PETROLATUM GAUZE DRESSINGS
ONE WAY VALVE DRESSING
GROUP 1A
GROUP 2A
VENT ON
VENT OFF
VENT ON
VENT OFF
STABILIZATION LUNGS COLLAPSED
GROUP 2B
GROUP 1B
VENT ON
VENT OFF
VENT ON
VENT OFF

Figure 1

ANESTHESIA ONLY
Vital Signs

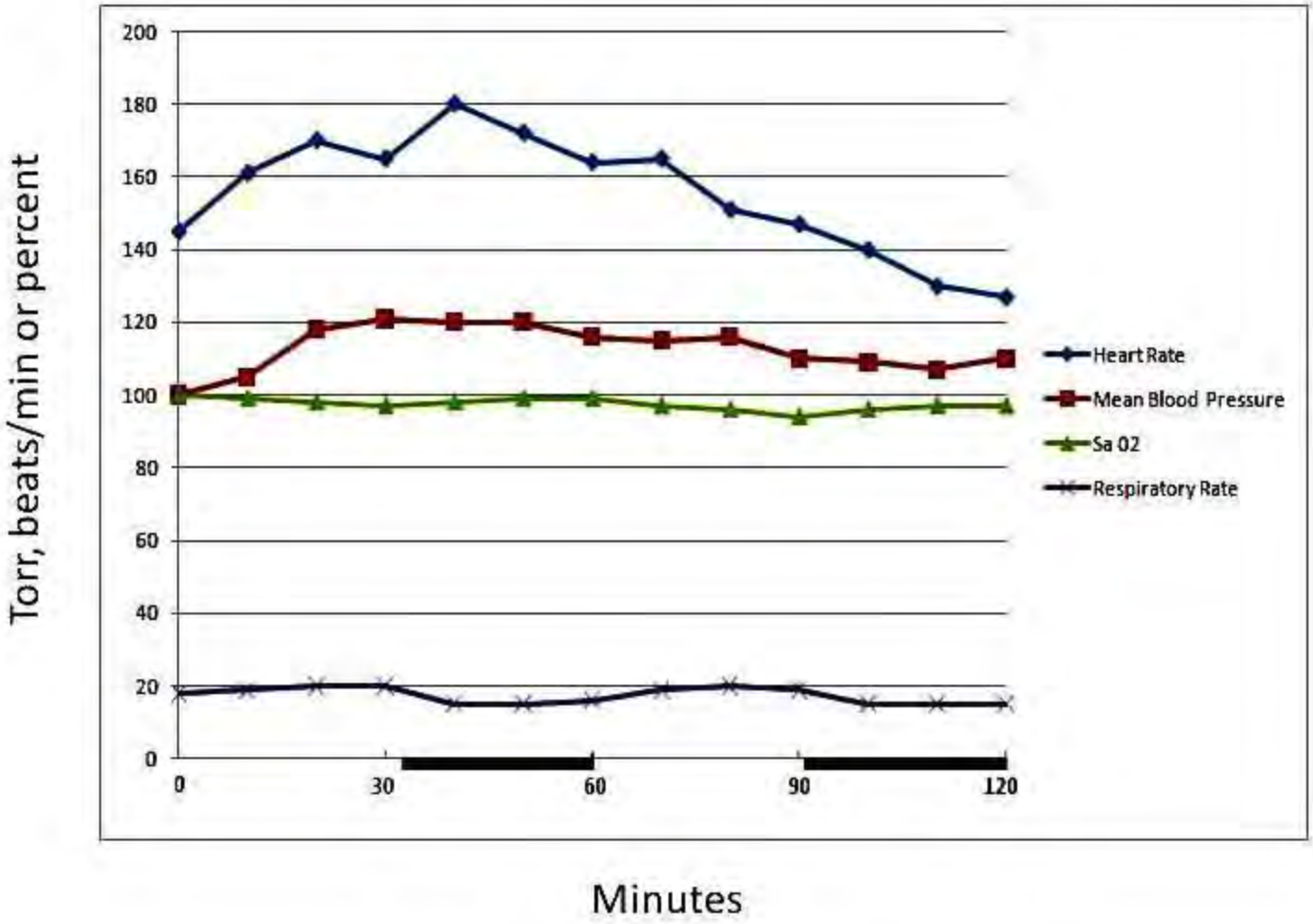


Figure 2

GAUZE DRESSINGS VERSUS VALVE DRESSINGS

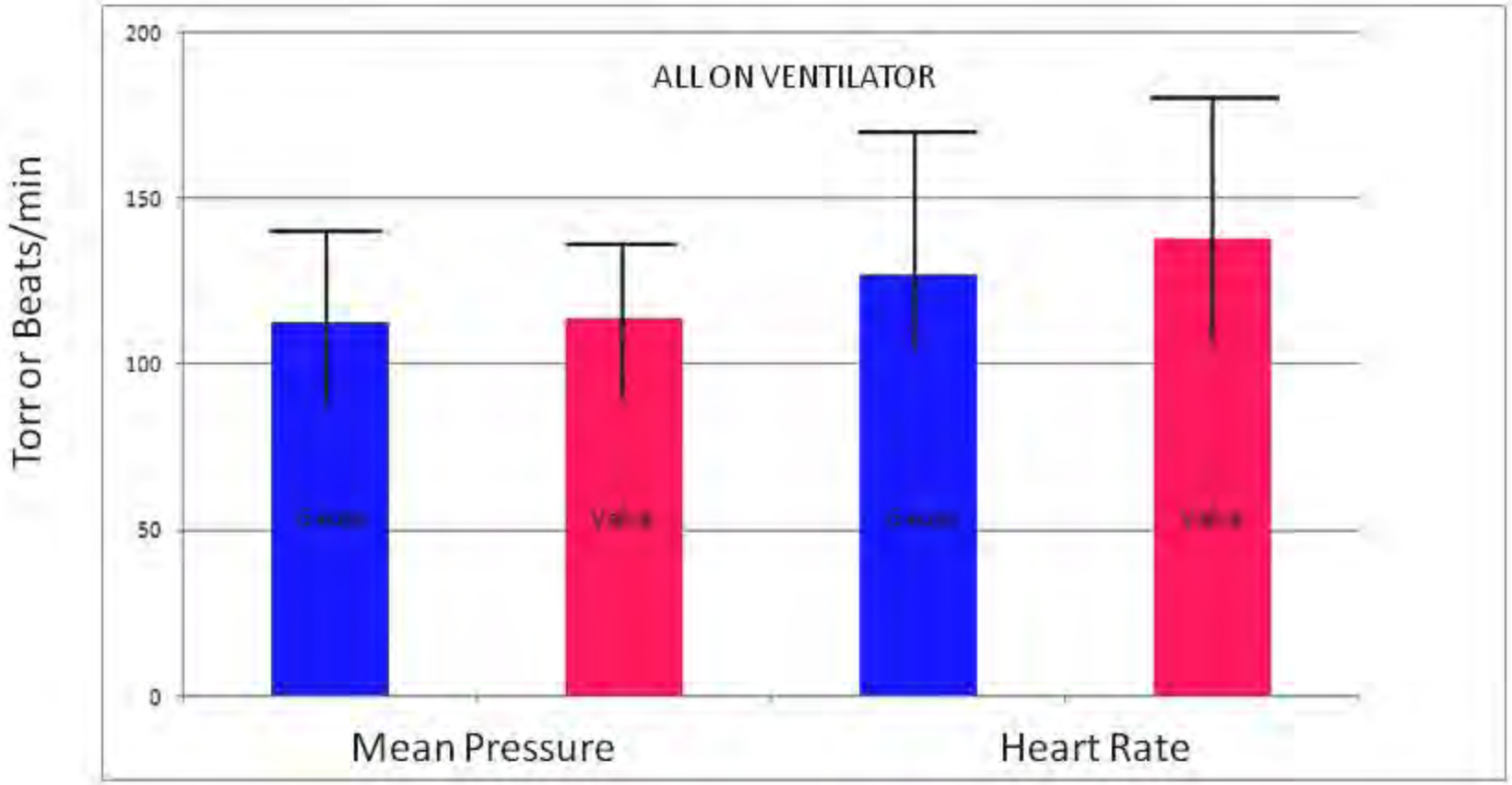


Figure 3

EARLY VERSUS LATE PERIODS

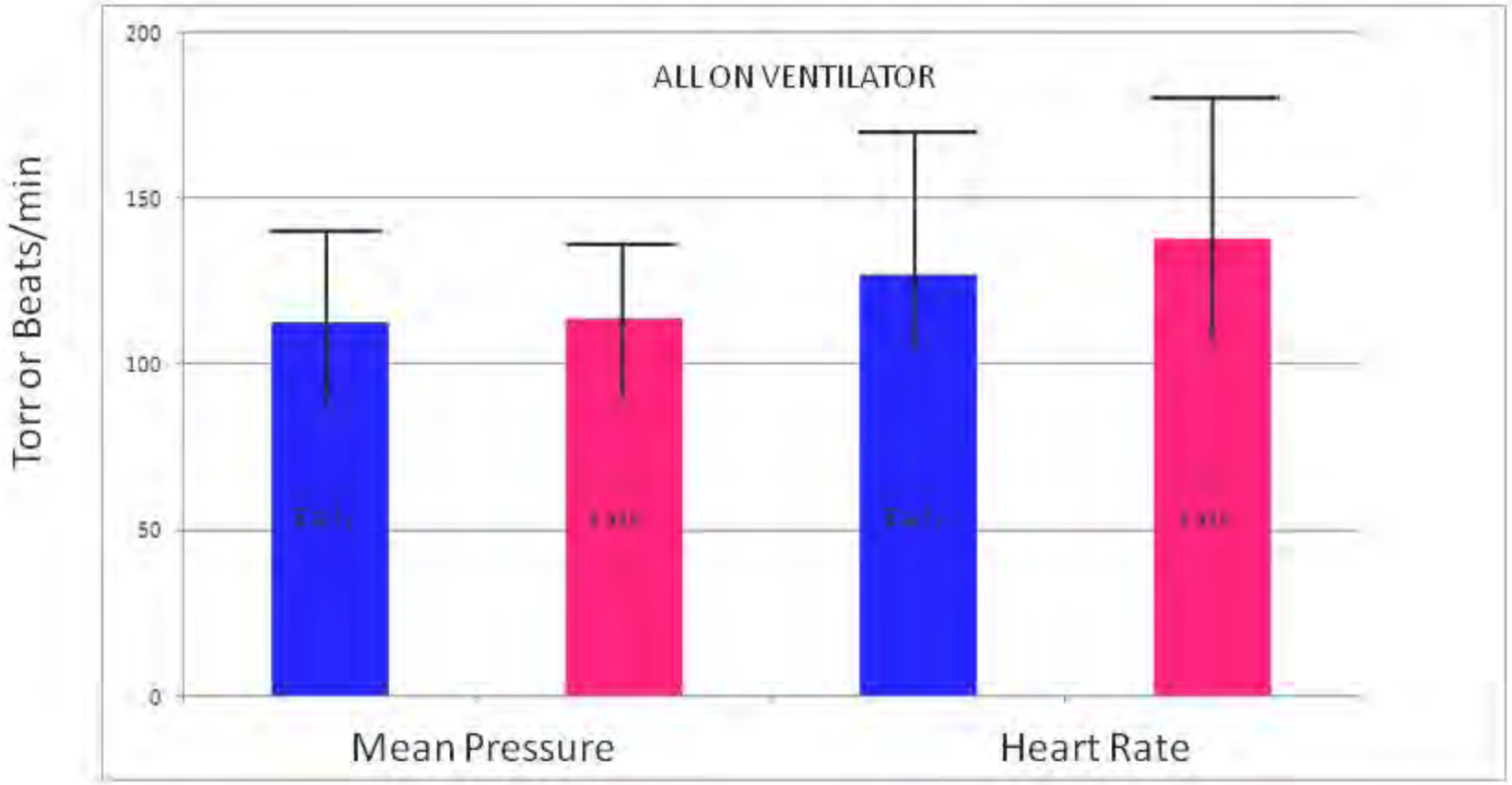


Figure 4

VALVE DRESSING WITHOUT VENTILATOR

Mean Arterial Pressure

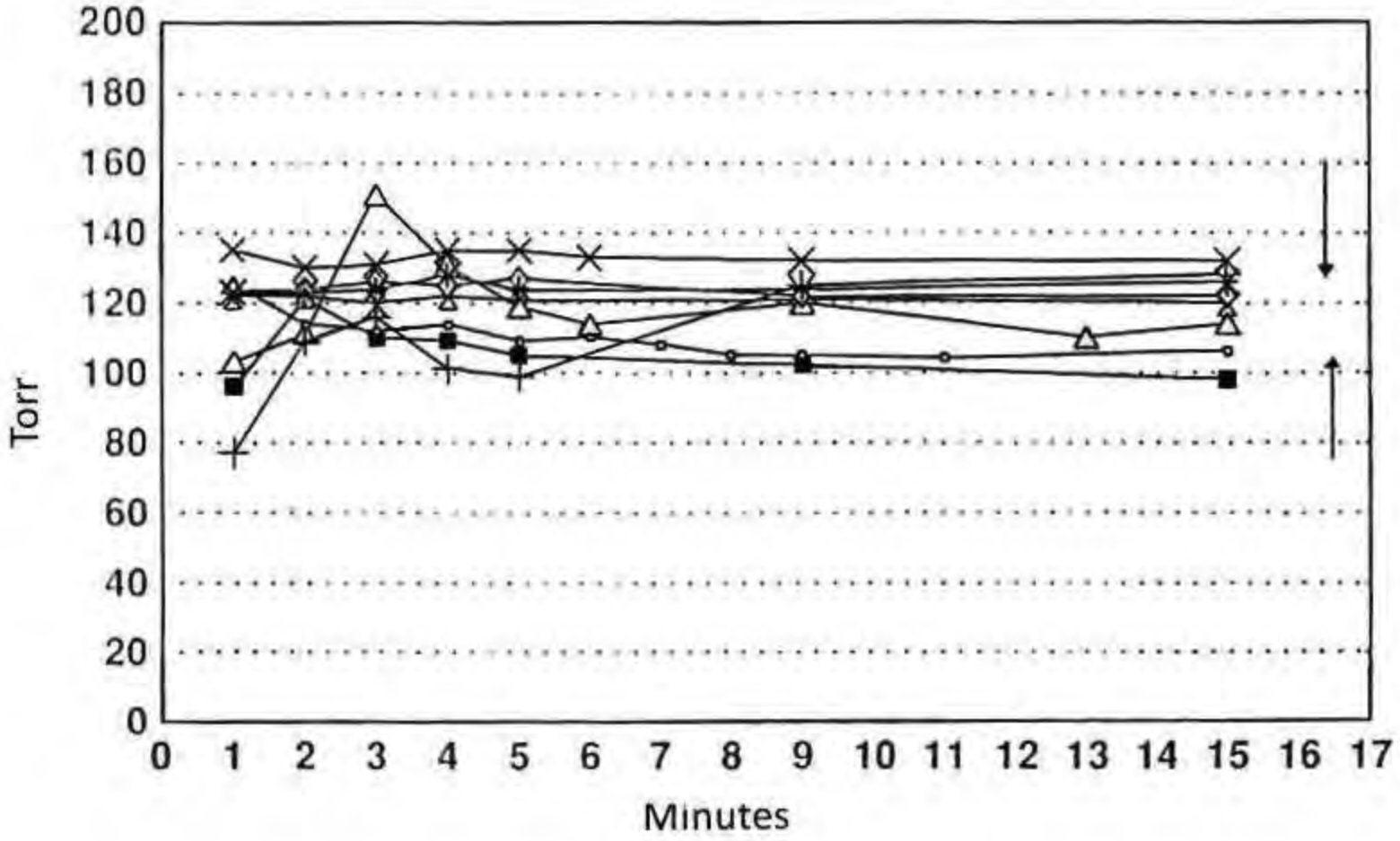


Figure 5

VALVE DRESSING WITHOUT VENTILATOR

Heart Rate

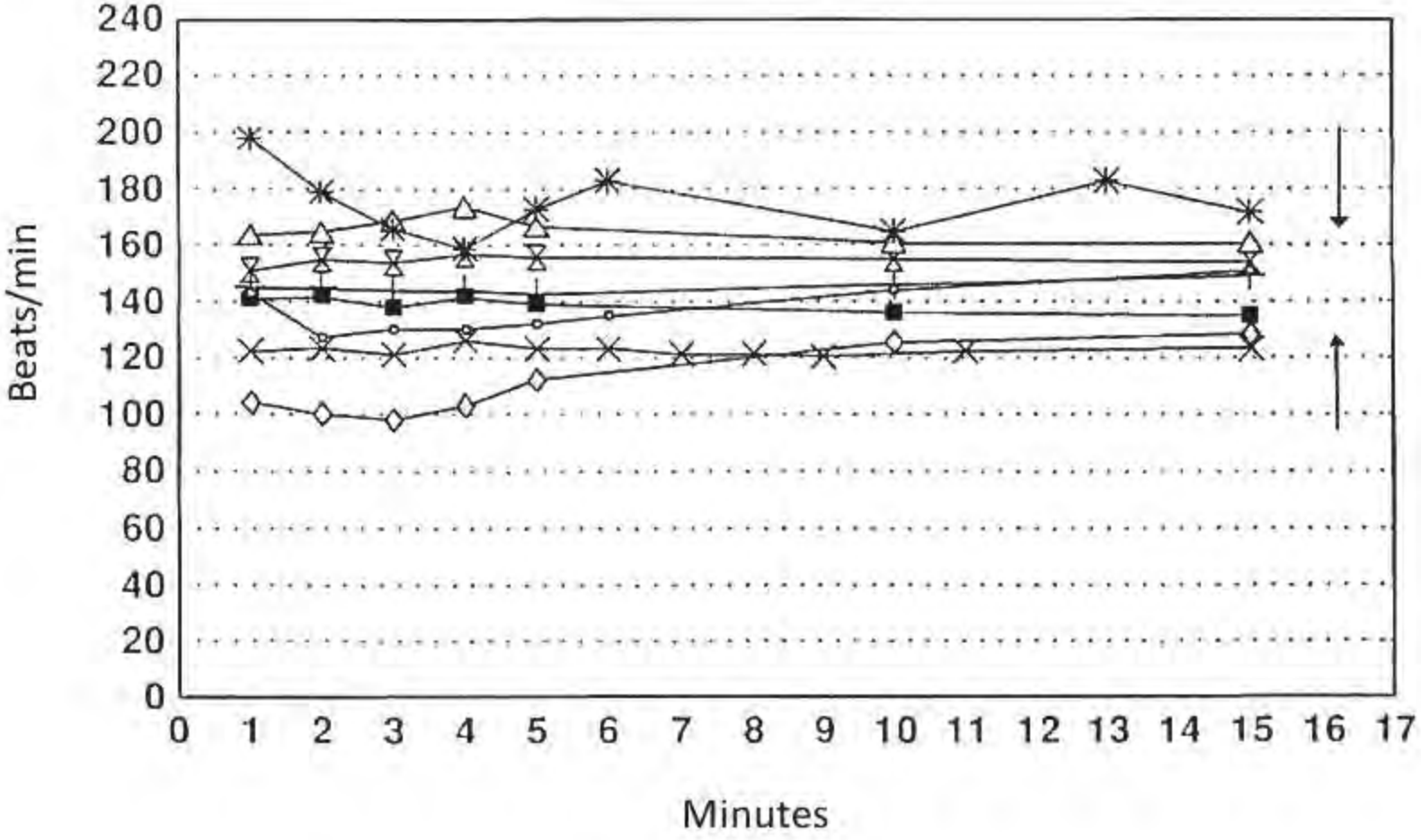


Figure 6

VALVE DRESSING WITHOUT VENTILATOR

Rescue Periods

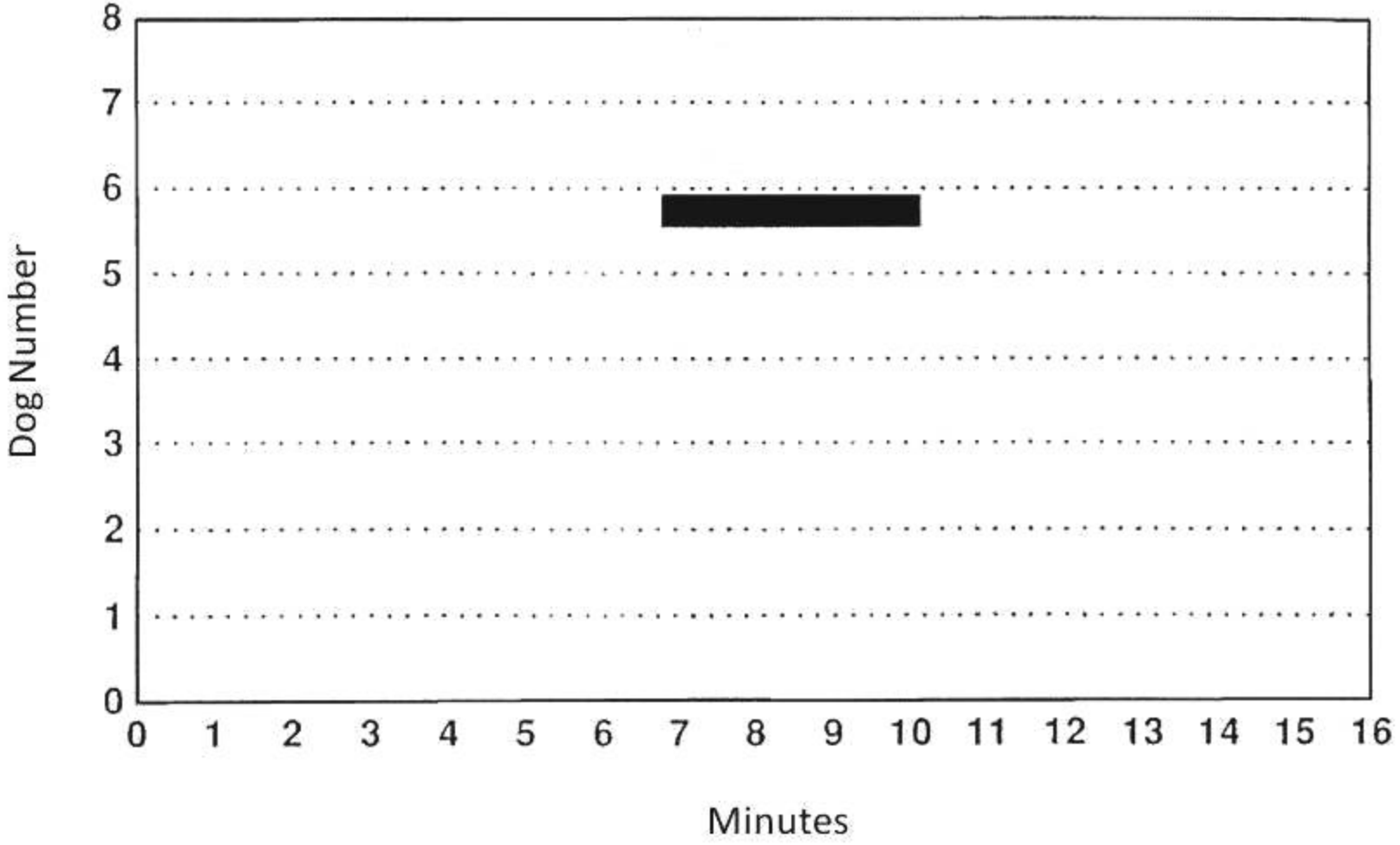


Figure 7

GAUZE DRESSING WITHOUT VENTILATOR

Mean Arterial Pressure

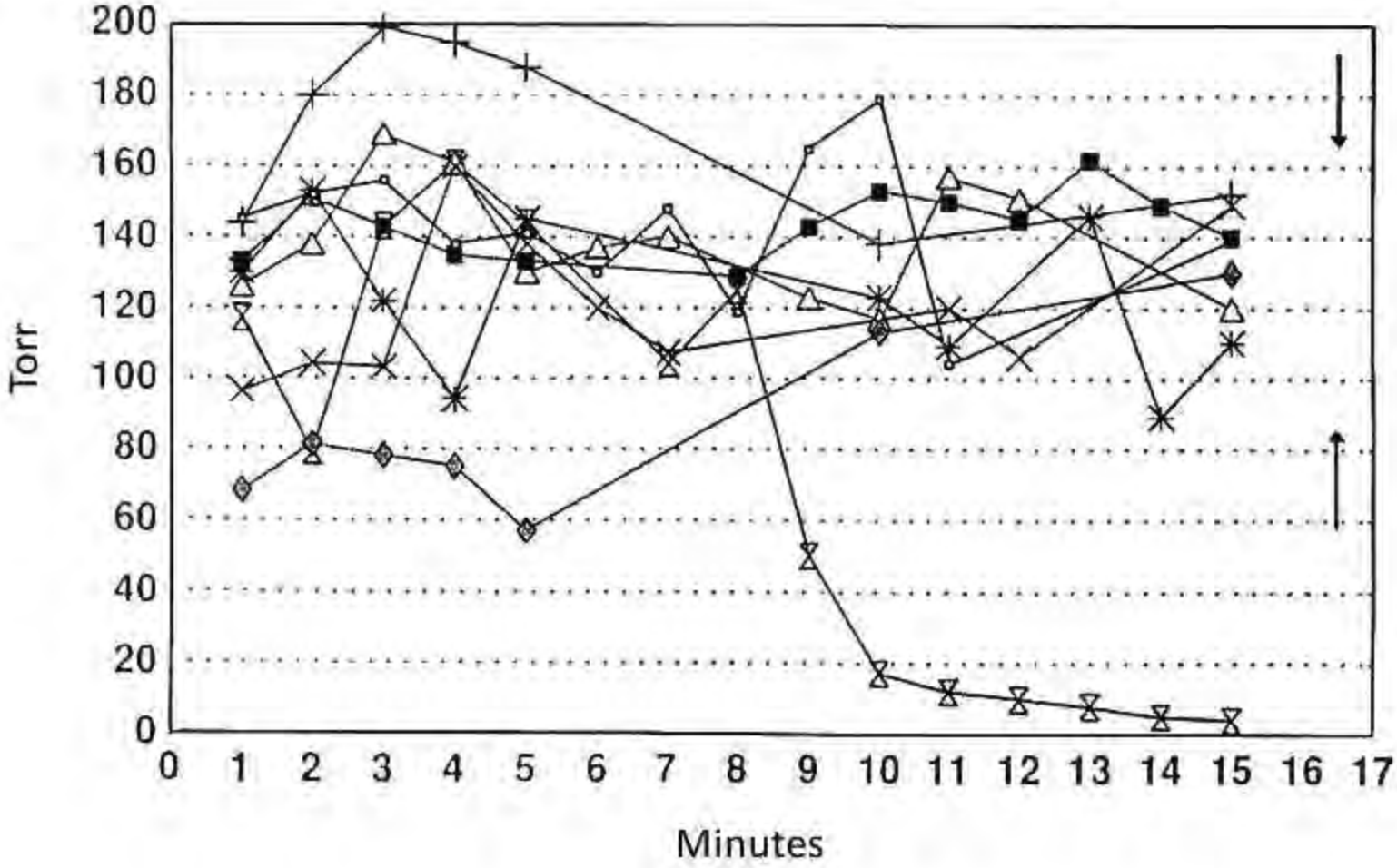


Figure 8

GAUZE DRESSING WITHOUT VENTILATOR
Heart Rate

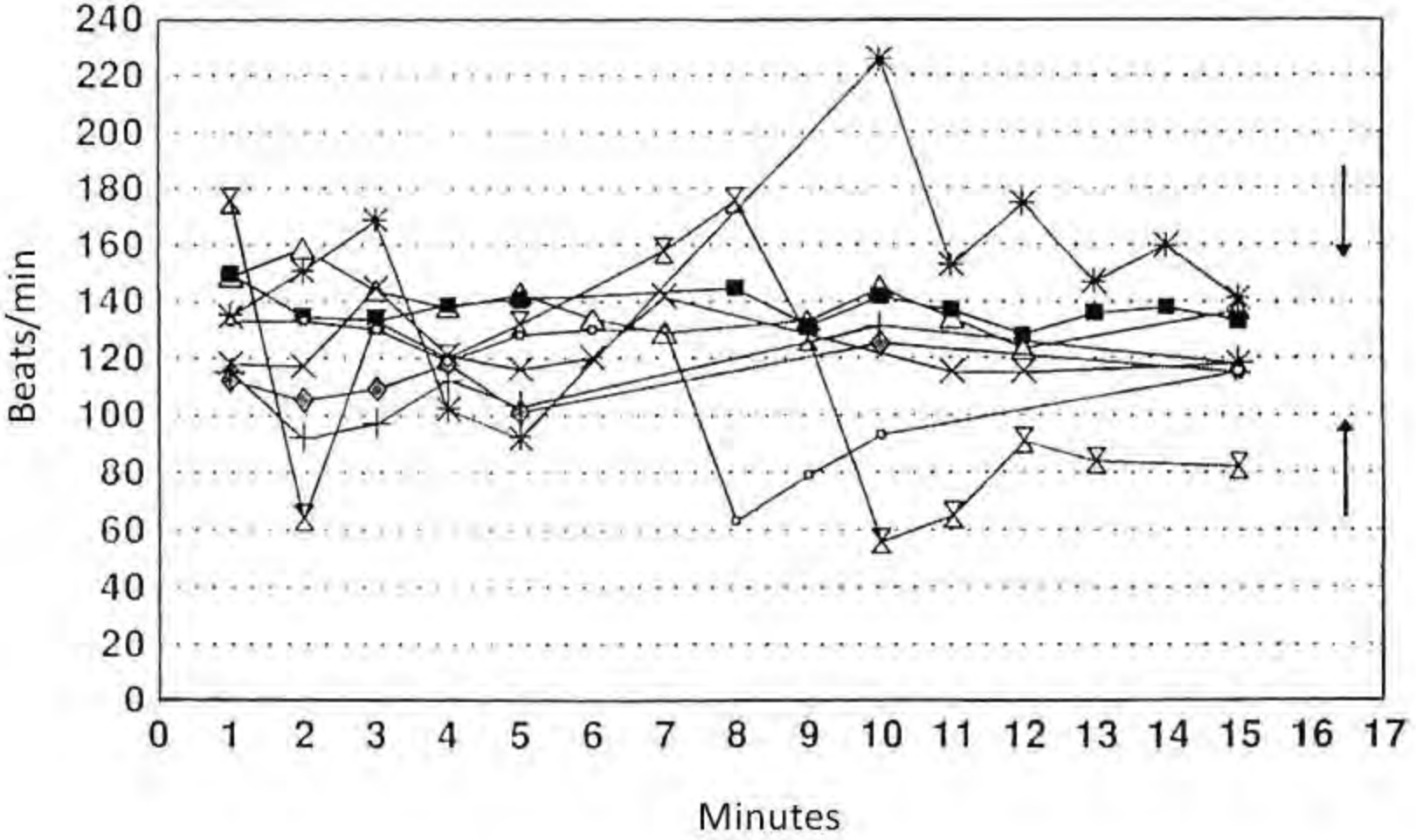


Figure 9

GAUZE DRESSING WITHOUT VENTILATOR

Rescue Periods

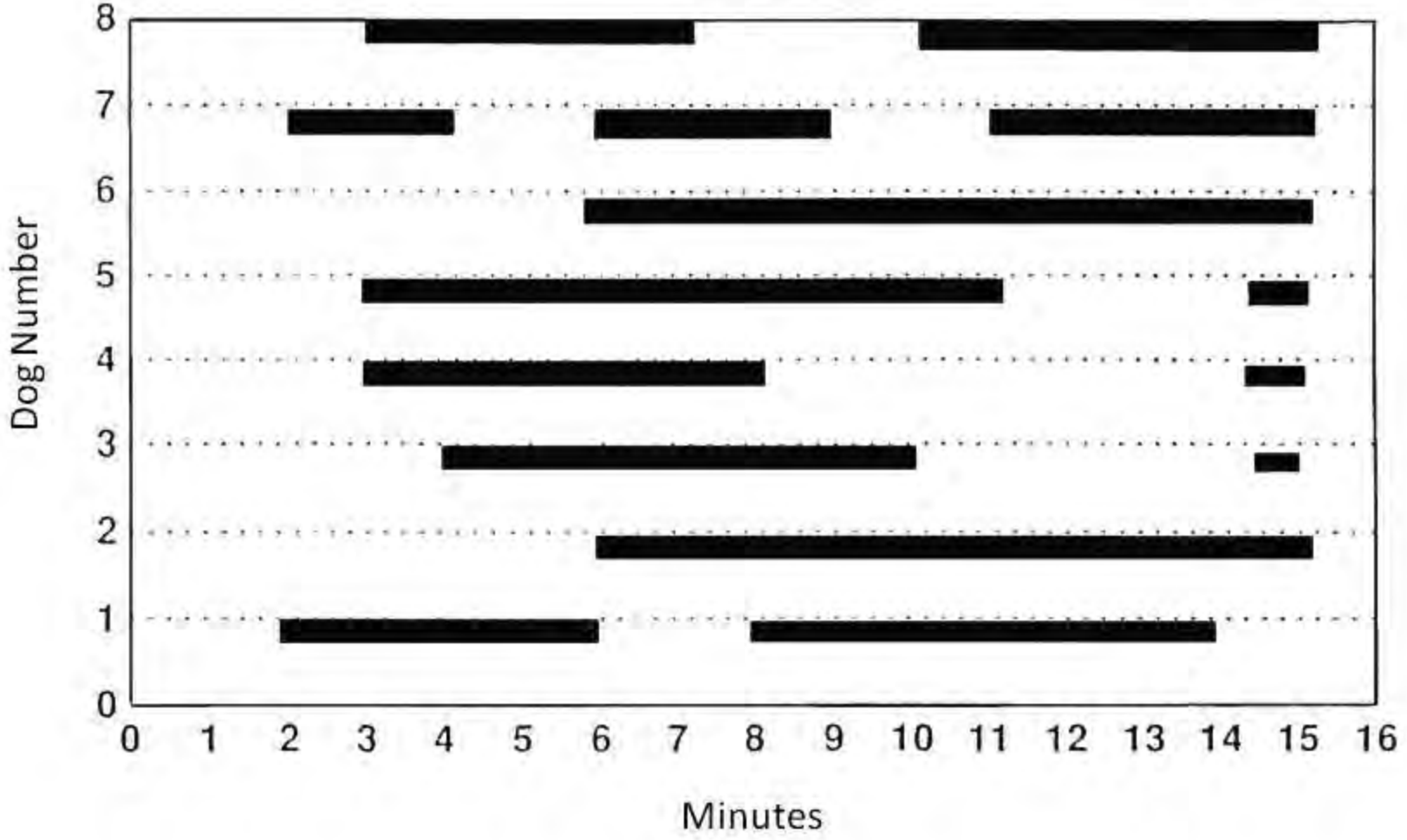
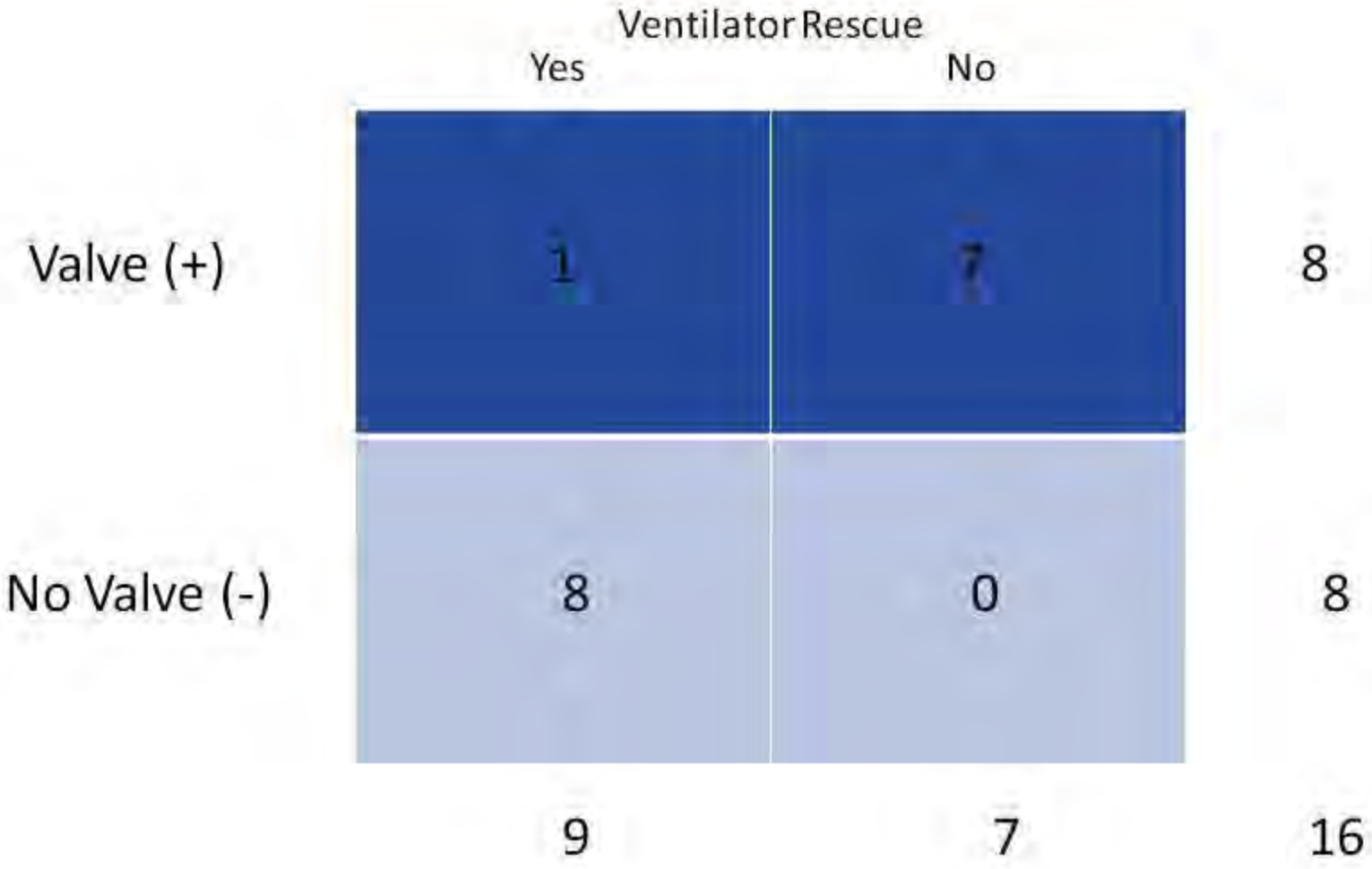


Figure 10

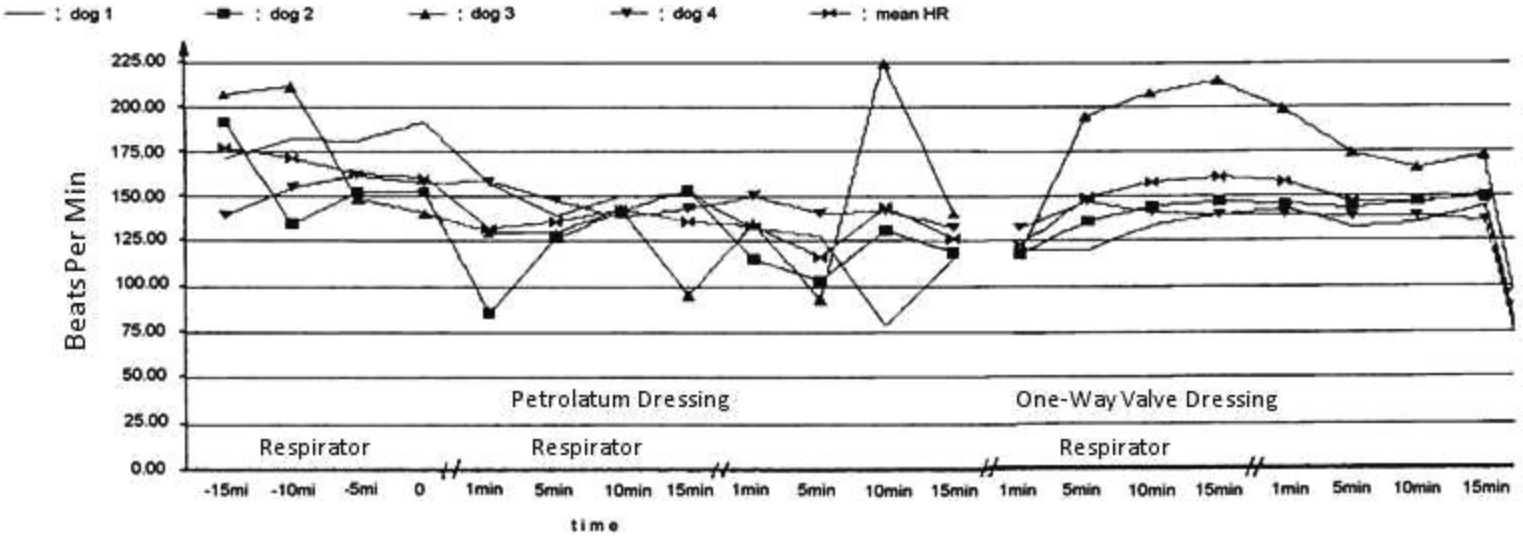
FISHER'S EXACT TEST



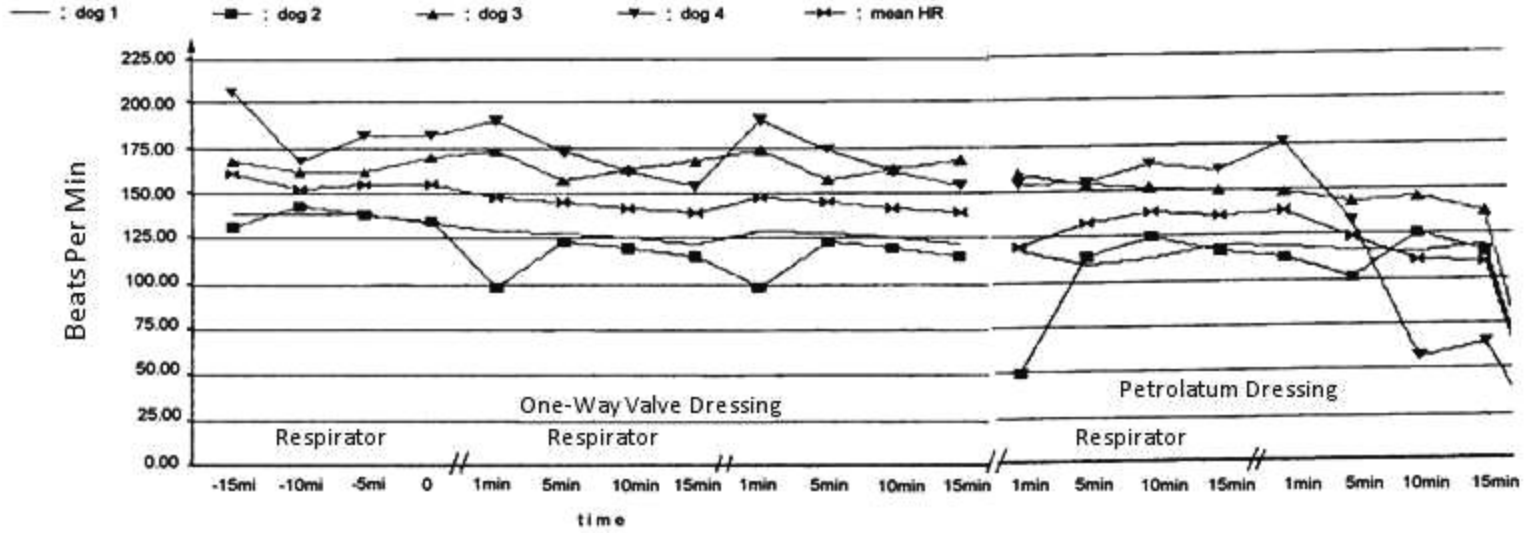
Two Tailed p-value = 0.0007

Figure 11

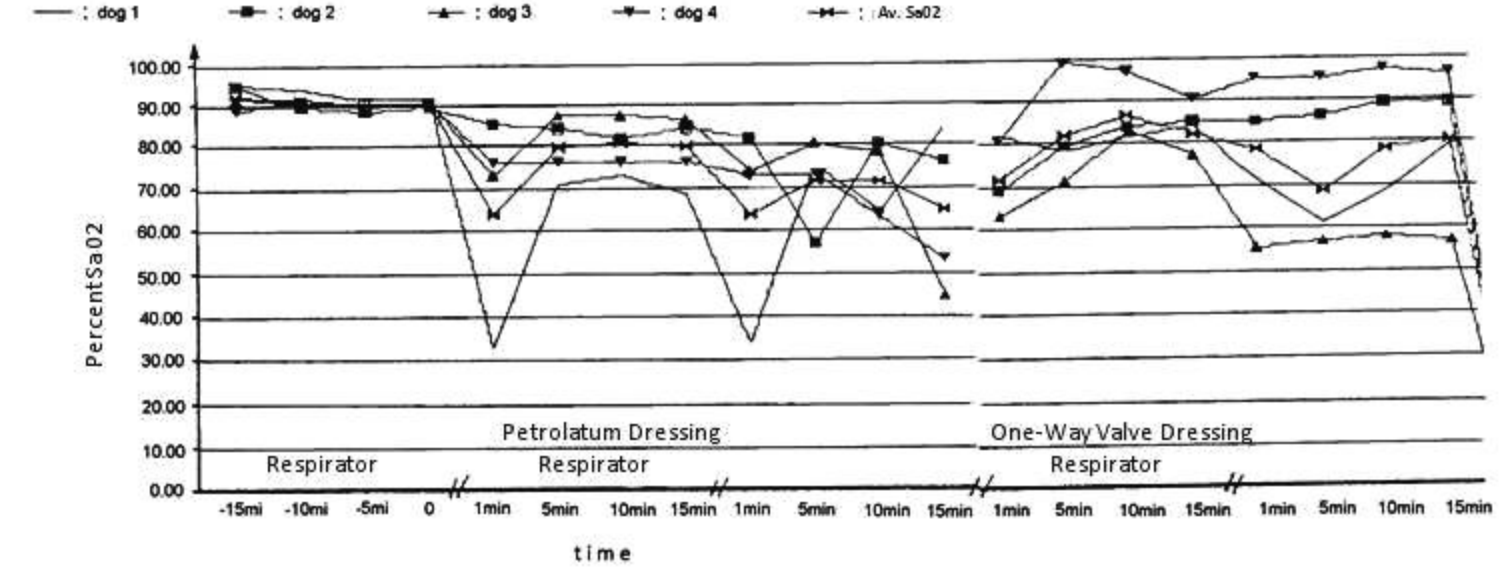
Group 2 Dogs – Heart Rate



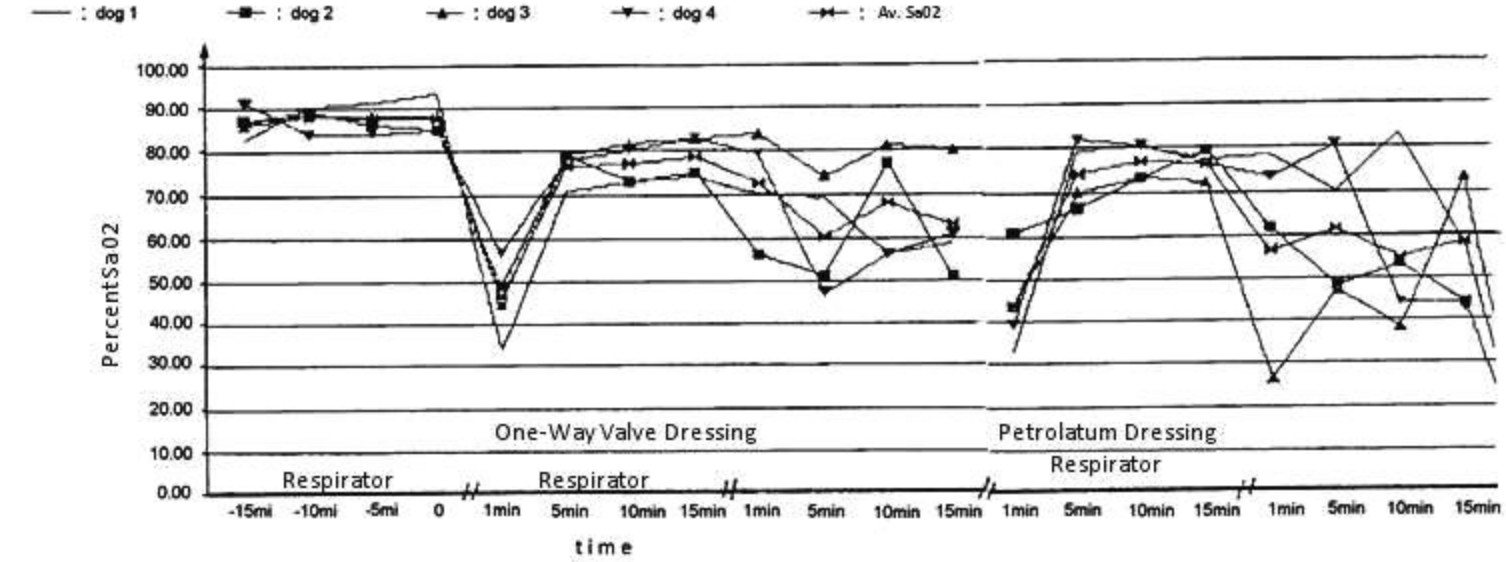
Group 3 Dogs – Heart Rate



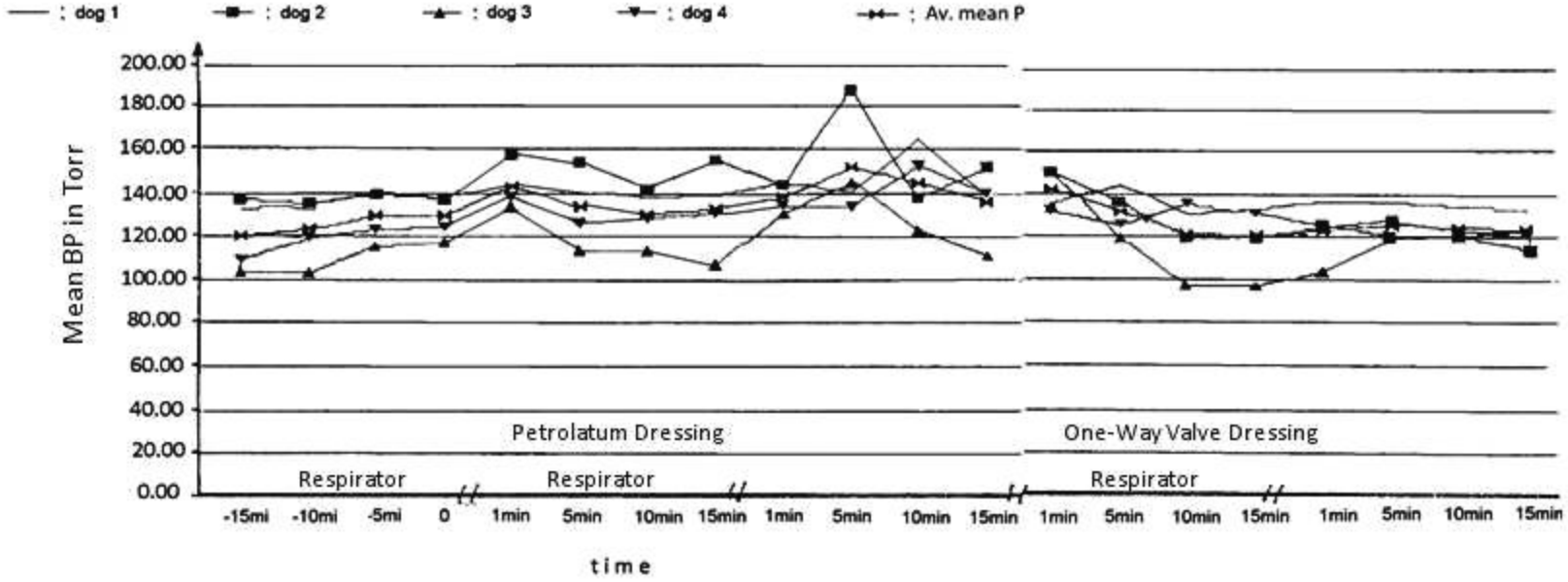
Group 2 Dogs – HGB 02 Saturation



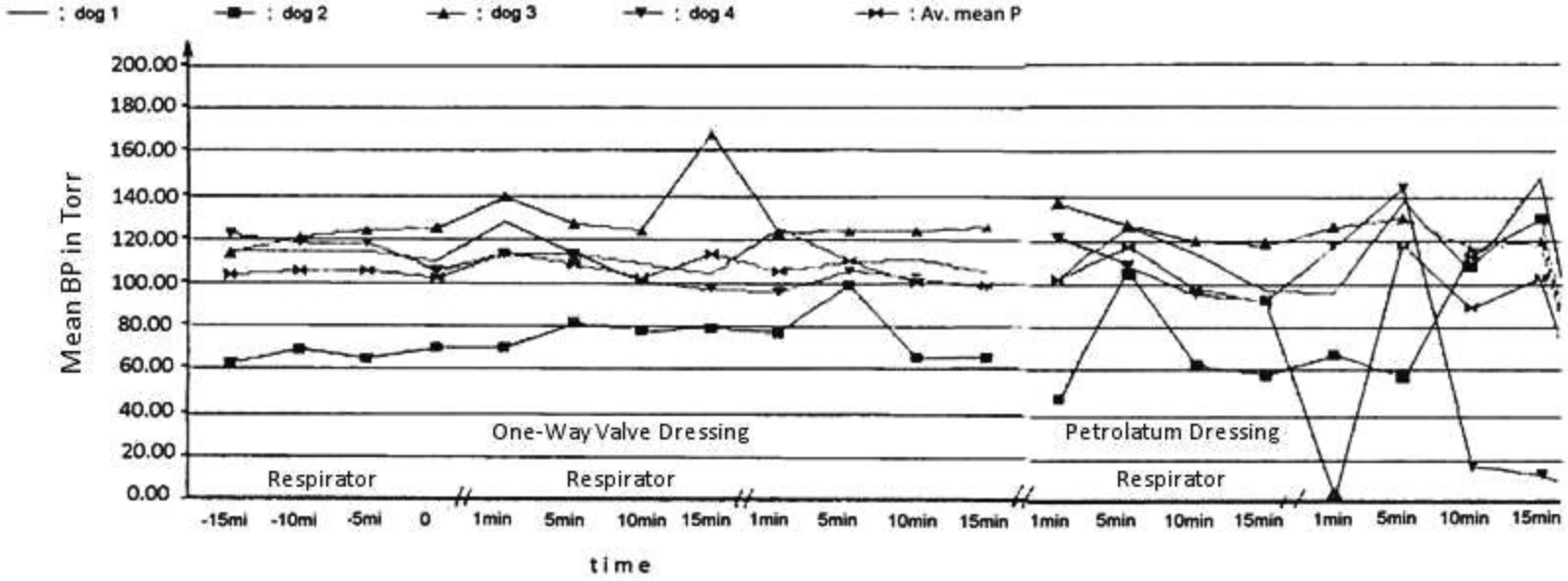
Group 3 Dogs – HGB 02 Saturation



Group 2 Dogs – Blood Pressure



Group 3 Dogs – Blood Pressure



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