Indian J. Vet. Surg. 35(2): 100-102, December 2014

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Dynamic lung compliance in cattle undergoing trans-abdominal diaphragmatic herniorrhaphy and right flank laparotomy

S. Senthilkumar[1†], V. Amritha[2], K. Jayakumar[1], A. Kumaresan[1], S. Kathirvel[3] and S. Dharmaceelan[4]

Tamil Nadu Veterinary and Animal Sciences University, Chennai (TN)

[1]Assistant Professor, [2]P.G. Student, [3]Associate Professor, [4]Professor, Department of Veterinary Surgery and Radiology, Veterinary College and Research Institute, Namakkal, Tamil Nadu-637 002

Received: July, 2014

The study was conducted on 12 animals divided into two equal groups to estimate the dynamic lung compliance in two groups of animals with or without diaphragmatic defect undergoing surgical interventions under isoflurane anaesthesia. In group I, transabdominal diaphragmatic herniorrhaphy was performed and in group II, right flank laparotomy was performed. Mechanical ventilation was initiated with the settings of 10 breaths/min, inspiratory time of 2 s, I:E ratio of 1:2. The peak inspiratory pressure (PIP) of 10 and 20 cmH_2O was maintained during surgery in group I and group II animals, respectively. The dynamic lung compliance was significantly (P<0.01) higher in group I animals than in group II. The mechanical ventilation with peak inspiratory pressure setting of 10 cmH_2O in group I animals during transabdominal herniorrhaphy maintained the cardiopulmonary parameters within the physiological limit and did not produce any deleterious effect on the lungs.

Key words: Cattle, Diaphragmatic herniorrhaphy, Laparotomy, Lung compliance.

Compliance is defined as the volume change per unit pressure change during inflation or deflation of a distensible structure (Thurmon *et al*., 1996). It is a measure of elasticity or distensibility of pulmonary or thoracic tissue and denotes the stretch ability of the lungs. It can be measured under static condition, i.e., at zero airflow or under dynamic condition. The dynamic lung compliance is easier to calculate as it does not require patient cooperation or inspiratory hold. Lung pathology and affections involving thoracic wall or diaphragm, directly or indirectly influence the lung compliance. Diaphragmatic defect in cattle may alter the lung compliance and may interfere with ventilation (Tranquilli *et al*., 2007). Mechanical ventilation is routinely used to prevent hypoxaemia and hypercapnia resulting from inadequate ventilation during diaphragmatic hernia repair (Hill *et al*., 1987; Romero and Rodgerson, 2010). Animals undergoing diaphragmatic hernia repair need acceptable ventilator settings during mechanical ventilation to avoid ventilator induced lung injury. An inappropriate tidal volume setting in patients with very compliant lung may over stretch the lung causing volutrauma during mechanical ventilation (Maclyntyre, 2004; Mulie *et al*., 2010). The study was designed to estimate the dynamic lung compliance in two groups of animals with or without diaphragmatic defect undergoing surgical interventions under isoflurane anaesthesia.

Materials and Methods

The study was conducted on 12 animals divided into two equal groups viz. group I and group II, based on the surgical interventions performed. In group I animals, transabdominal diaphragmatic herniorrhaphy was performed. Exploratory laparorumenotomy under left paravertebral analgesia was done 48 hr prior to diaphragmatic herniorrhaphy to confirm diaphragmatic hernia as well to reduce rumen load to facilitate diaphragmatic defect closure. In group II animals, right flank laparotomy was performed to correct intussusception by enterectomy and entero-anastomosis. In all the animals food and water were withheld for 24 hr and 12 hr, respectively prior to induction of anaesthesia. The marginal auricular vein was canulated with an 18 G 1.77 inch intravenous canula (BD Venflon™, Becton Dickinson Infusion Therapy, Sweden) and secured *in situ.* Acepromazine 0.04 mg/kg b.wt was administered i.v. 5 min prior to induction of anaesthesia. Guaifenesin as a 5% solution in dextrose normal saline and ketamine HCl at the dose rate of 50 mg and 4 mg/kg b.wt, respectively, were administered i.v. to induce anaesthesia. Endotracheal intubation with an 18 mm i.d. cuffed Murphy type endotracheal tube was performed and the cuff was inflated to secure the airway leak free. The endotracheal tube was connected to the Y

†Corresponding author; E-mail: ssenthilvet@gmail.com

piece of the breathing tube and the oxygen flow rate was set at 10 L/min for the first three minutes to facilitate denitrogenation of the circle. The oxygen flow rate was subsequently reduced to 10 mL/kg b.wt/min employing total rebreathing system using Mallard Medical Model 8300C large animal anaesthetic machine. The vapourizer setting was altered to maintain uniform plane of surgical anaesthesia. Mechanical ventilation was initiated with the settings of 10 breaths/min, inspiratory time of 2 s, I:E ratio of 1:2. The peak inspiratory pressure (PIP) of 10 and 20 cmH_2O was maintained during surgery in group I and II animals, respectively. The tidal volume delivered was recorded. The positive end expiratory pressure (PEEP) was maintained at 3 cmH_2O during mechanical ventilation. The peak inspiratory pressure was increased to 15, 20, 25 and 30 cmH_2O for two or three breaths and the corresponding tidal volume delivered was noted. In group I animals, the tidal volume recording was done after separating the adhesions from the diaphragm and prior to suturing of diaphragmatic defect. The lungs were fully inflated to a PIP of 30 cmH_2O before absolute closure of diaphragm to reestablish sub atmospheric pressure within the pleural cavity. The dynamic lung compliance was calculated by the below mentioned formula as described by Swagatha and Narasimman (2011).

Dynamic lung compliance= Tidal volume/ (PIP-PEEP)

The cardiopulmonary parameters viz. pulse rate, saturation of peripheral oxygen, end tidal carbon dioxide and mean arterial pressure were monitored continuously and recorded at 10 min interval using Welch Allyn vital sign monitor. The intended surgical interventions were carried out as per the standard surgical techniques prescribed. The animals were weaned from mechanical ventilation by gradually decreasing the respiratory rate and mechanical ventilation was discontinued on resumption of spontaneous ventilation. On completion of the surgical procedure, the administration of isoflurane was discontinued and oxygen administration increased to 10 L/min with APL valve opened. The endotracheal tube was left *in situ* till swallowing reflex resumed and it was removed with partially inflated cuff in animals which had regurgitation episode during anaesthesia. In other animals, the endotracheal tube was removed with cuff deflated. The animals were placed in a quite recovery area and left undisturbed and allowed to recover on their own. The data obtained were analyzed employing t-Test: Two-Sample Assuming Unequal Variances using Microsoft Excel 2007.

Results and Discussion

The mean±SE of bodyweight of the animals and the dynamic lung compliance in groups I and II were 335.0±6.70 kg and 410.80±29.65 mL/cmH_2O, and 315.71±29.79 kg and 217.58±9.72 mL/cmH_2O, respectively. Statistical comparison revealed no significant difference in the body weight between groups. The dynamic lung compliance was comparatively higher in group I animals than in group II and differed significantly ($P<0.01$). Higher lung compliance in group I could be due to over inflation of lung owing to the presence of diaphragmatic defect. MacIntyre (2004) reported that mechanical ventilation with routine peak inspiratory pressure setting in a highly compliant lung might result in over inflation of lung due to larger tidal volume delivery. Mulie *et al*., (2010) observed that very compliant lung might receive an excessive tidal volume during mechanical ventilation and concluded that peak inspiratory pressure cannot be taken into account to prevent ventilator induced lung injury. Volutrauma is

Table 1: Cardiopulmonary parameters recorded at 10 min intervals during maintenance of anaesthesia.

Time interval/ Parameters	10 min		20 min		30 min		40 min	
	G I	G II	G I	G II	G I	G II	G I	G II
Pulse rate (beats/min)	82.10^{ab}± 1.38	85.80^{b} ±3.03	84.40^{b} ±3.74	84.60^{ab} ±3.18	83.90^{B} ±2.90	78.10^{A} ±4.30	79.10^{ab} ±1.87	82.10^{ab} ±1.38
Saturation of peripheral oxygen (%)	97.00 ±0.51	97.80 ±0.55	96.50 ±0.45	96.70 ±0.53	98.80 ±0.96	95.50 ±0.45	97.50 ±0.85	96.80 ±0.55
End tidal carbon dioxide (mm Hg)	55.99^{B} ±0.97	51.02^{A} ±1.02	57.65^{B} ±0.92	50.08^{A} ±1.06	56.87^{B} ±0.17	51.32^{A} ±2.03	55.99^{B} ±1.07	52.05^{A} ±2.08
Mean arterial pressure (mm Hg)	90.97^{A} ±5.26	85.00^{B} ±2.51	87.85^{A} ±4.28	87.00^{A} ±1.54	89.97^{A} ±2.36	83.00^{B} ±2.51	90.17^{A} ±4.86	83.02^{B} ±2.57

Row-wise group means with different superscripts (abcde) differ significantly at $P<0.05$ and those bearing upper case (ABCDE) differ significantly at $P<0.01$.

possible in very compliant lungs with a low airway resistance when pressure is continuously above 20 cmH_2O. Tanskanen *et al.* (1997) reported that the dynamic lung compliance in the lateral and the prone positions of human patients was significantly lower than in the supine position at 15 min ($P < 0.01$) and 1 hr ($P < 0.001$) after the posture change. Insufflating lungs above its capacity causes volutrauma and at pressure above 30 cmH_2O the alveoli suffer barotrauma. Volutrauma, however, is more important than barotrauma as lung inflation above the total lung capacity is more dangerous than inflation to a high pressure with a small lung volume. The cardiopulmonary parameters recorded during maintenance of anaesthesia were presented in Table 1. The cardiopulmonary parameters recorded during the study were within the physiological limit. The mechanical ventilation with peak inspiratory pressure setting of 10 cmH_2O in group I animals during transabdominal herniorrhaphy maintained the cardiopulmonary parameters within the physiological limit and did not produce any deleterious effect on the lungs.

Acknowledgements

The authors also express their sincere gratitude to College of Veterinary Medicine, Michigan State University, USA for the benevolence to donate the large animal anaesthetic machine to Department of Veterinary Surgery and Radiology, Veterinary College and Research Institute, Namakkal.

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