



Peri-operative monitoring of general anaesthesia in buffaloes undergoing diaphragmatic herniorrhaphy in relation to pleural integrity and survivability

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Diaphragmatic hernia (DH) is a chronic condition in buffaloes (Singh *et al.* 2006), where, there is rupture of diaphragm at the musculo-tendinous junction due to multiple etiologies and the reticulum is commonly herniated into the thoracic cavity (Singh *et al.* 2006). General anaesthesia (GA) in dorsal recumbency is recommended for the treatment of DH in buffaloes.

The GA in bovine is a challenge due to commonly occurring complications. Diaphragmatic herniorrhaphy is done after rumenotomy (complete emptying of rumen) to avoid regurgitation during GA and also to allow space for the suturing of the diaphragm. The increased intra-thoracic pressure due to ruminal tympany (which is common in many buffaloes) and the pressure of herniated organ on the heart, posterior vena cava, aorta and the lungs develop a compromised ventilation-perfusion state leading to ischemia/ reperfusion in internal organs, and this condition gets aggravated when the affected bovine is subjected to herniorrhaphy in dorso-ventral position (Bisla *et al.* 2003). Midazolam is a commonly used benzodiazepine pre-anaesthetic agent having a potent anxiolytic, hypnotic, sedative, anticonvulsant and skeletal muscle relaxant action, with minimal adverse effects on the cardiovascular system (Riss *et al.* 2008, Barash *et al.* 2009).

Buffaloes have the tendency to form tough adhesions at the site of hernia ring, to localize the condition. The presence of severe adhesions of the herniated reticulum with the ring and cranially with the pleura and sometimes with the lungs or heart (Saini *et al.* 2000) are to be broken to bring the reticulum back into the abdominal cavity, and for the suturing of the diaphragm. This act of breaking of adhesions, many times leads to the rupture of pleura or any other major organ/blood vessel. Intermittent positive pressure ventilation (IPPV) is recommended during herniorrhaphy as most of the buffaloes are not able to effectively respire.

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It was hypothesized that the rupture of pleura may alter the peri-anaesthetic monitoring parameters and may affect the survival status of the buffalo. So the aim of this study was to evaluate the peri-operative anaesthetic parameters for the buffaloes undergoing diaphragmatic herniorrhaphy under general anaesthesia in relation to pleural integrity and survivability.

A total of 31 buffaloes which underwent diaphragmatic herniorrhaphy under midazolam-propofol-isoflurane anaesthesia in a period of one year (2021) were included in the study. The DH was diagnosed using radiography and/or ultrasonography.

Diaphragmatic hernia repair was done as described by Singh *et al.* 1977. Pre-anaesthesia was given with Inj. midazolam @ 0.2 mg/kg body weight intravenously. Induction was done with inj. Propofol @ 2 mg/kg body weight, intravenously, till effect after 5 min of pre-anaesthetic. Endotracheal intubation was done using 18-22 mm internal diameter tube. Anaesthesia was maintained with Isoflurane mixed in 100% oxygen.

Intermittent positive pressure ventilation (IPPV) was given to all the buffaloes once the ring was free of adhesions or as per the requirement. Hyper-ventilation of the lungs was done (up to 30 psi) at the tightening of last suture on the diaphragm. Suction of free air in the pleural space was started once the ring was sutured, through a 4 inch sterile stainless steel needle inserted in the right chest cavity (between lung/pleura and diaphragm) at the level of 3rd/4th ICS in dorsal recumbency. Once, the surgery was complete, the buffaloes were slowly brought back to lateral recumbency and were monitored for recovery.

The perioperative parameters were recorded manually or using a multi para-monitor of 'Surgivet' make. Herniorrhaphy parameters viz. duration of surgery (in min); skin incision to end of skin suturing; movement of buffalo head/limbs during skin incision; blood loss during surgery was assessed based on the number of gauze pieces soaked in blood; any foreign body recovered from the outside of reticulum in chest during herniorrhaphy; intactness of pleura during breaking of adhesions. were

recorded in all the buffaloes. Peri-anesthetic parameters including respiration rate (RR), heart rate (HR), body temperature ($^{\circ}\text{F}$), blood pressure (systolic, diastolic and mean), corneal reflex, palpebral reflex, pupil size, position of eyeball, lacrimation, salivation, regurgitation, saturation of peripheral oxygen (SpO_2), end tidal carbon dioxide (EtCO_2), oxygen flow rate and isoflurane % were recorded every 5 min. Recovery (Rough or smooth) and post-operative complication if any (regurgitation, salivation and apnea) were also noted.

The peri-operative anesthetic monitoring data was compared between anesthetic survivors (Group 1, $n=26$) and non-survivor (Group 2, $n=5$) and between intact pleura (Group 3, $n=21$) and ruptured pleura (Group 4, $n=10$) buffaloes during herniorrhaphy. Microsoft excel 10 was used to calculate the descriptive statistics. Subjective data was evaluated on % basis. The student's t-test was used to calculate the test of significance for the difference between groups wherever required.

Out of total of 31 buffaloes included in the study, 26 buffaloes were anaesthetic survivors (S, Group 1) and 5 were non-survivors (NS, Group 2). The Group 3 (intact pleura during herniorrhaphy) contained 21 buffaloes and Group 4 (ruptured pleura during herniorrhaphy) had 10 buffaloes.

Herniorrhaphy findings: The duration of herniorrhaphy was non-significantly higher in Group 1 as compared to Group 2. Majority of buffaloes did not show skin movement during incision in both the groups. The blood loss during herniorrhaphy was mild in majority of buffaloes of Group 1 (69.23%) and moderate in Group 2 (40%). Pleura got ruptured during the act of breaking adhesions in 80% of Group 2 buffaloes while in only 23.07% of Group 1. The ruptured pleura restricts the lung expansion by increasing the sub-atmospheric pressure within the thorax and thus leading to hypoventilation state.

Peri-anaesthetic monitoring: There was mild to moderate loss of palpebral reflex whereas corneal reflex was present in majority of the animals after midazolam administration. Loss of eyelash reflex, mild to moderate palpebral reflex and full corneal reflex after midazolam administration has been reported in bovines (Kaur and Singh 2004). Propofol administration resulted in abolition of palpebral reflex in majority of buffaloes; however, moderate corneal reflex was present throughout the procedure in Group I. At the Stage III, surgical plane of anaesthesia most of the buffaloes tested negative or had mild palpebral reflex. However, after about 5 min of withdrawal of isoflurane in all the buffaloes in Group I, the reflexes started reappearing. Similar observations have been reported after thiopental induction in herniorrhaphy undergoing buffaloes (Ninu *et al.* 2015).

Comparison of Peri-anaesthetic parameters among Group I (S=Survivors) and Group II (NS=Non-Survivors)

Corneal reflex: The corneal reflex was always more than 50% in Group I (Fig. 1a). Corneal reflex may be missed, due to dryness of the cornea. The corneal reflex, if is absent was considered alarming, and if was absent along with dilated

Table 1. Herniorrhaphy findings in Group 1 and 2 buffaloes

Herniorrhaphy findings	Group 1 ($n=26$)	Group 2 ($n=5$)
Duration of surgery (min)	72.71 $\pm$ 14.82 (50-100)	55 $\pm$ 16.83 (45-80)
<i>Movement during skin incision</i>		
Yes	10/26=38.46%	2/5=40%
No	16/26=61.54%	3/5=60%
<i>Blood loss</i>		
Mild	18/26=69.23%	1/5=20%
Moderate	5/26=19.23%	2/5=40%
Severe	3/26=11.54%	2/5=20%
<i>Retrieval of foreign body during herniorrhaphy</i>		
Yes	3/26=11.54%	
No	1/26=3.85%	1/1=100%
<i>Integrity of pleura</i>		
Intact	20/26=76.92%	1/5=20%
Ruptured	6/26=23.07%	4/5=80%

pupil, was the only indication of death in this position in buffaloes as the other life parameters may not be correctly shown by the pulse oximeter in dorsal recumbency and the respiration was mostly absent, when the diaphragm was free of adhesions.

Eyeball position: The eyeball position was recorded as ventro-medial or central (Supplementary Fig. 1). The central eyeball was recorded when the anaesthetic plane was light or in grade 4 or at recovery (Hall *et al.* 2001). In Group 1, the eyeball position was ventromedial during surgery in most of the buffaloes and was central either at premedication or at recovery time. While in the Group 2, the eyeball came to central position with no buffalo showing it ventromedial as and when the buffalo was dead. Downward rotation of eyeball has been reported in cow calves during propofol anaesthesia (Genccelep *et al.* 2005).

Lacrimation: Lacrimation was recorded in higher percentage of Group 2 buffaloes than the Group 1, and lacrimation stopped in Group 2, only when the buffalo collapsed during surgery (Supplementary Fig. 2).

Salivation: The salivation was almost equally present in both Group I and II of buffaloes, but showed reduction in percentage of buffaloes of Group II with time (Supplementary Fig. 3). Increased salivation recorded during present study might be due to decreased swallowing reflex (Kakkonen and Erikson 1987).

Regurgitation: Regurgitation was noticed in a small percentage of buffaloes in both the groups. Regurgitation was observed either at induction in lateral recumbency or after completion of surgery, while making the buffalo lateral again from dorso-ventral position as the cardia was dipped in reticulum in this position only (Supplementary Fig. 4). Mild to moderate regurgitation in DH bovines after midazolam-thiopentone administration was reported by Kaur and Singh 2004.

Palpebral reflex: The palpebral reflex showed an inverted bell shape curve in Group 1, with the reflex reducing with time, when the buffaloes were in surgical plane of anaesthesia and then gradually increased as the

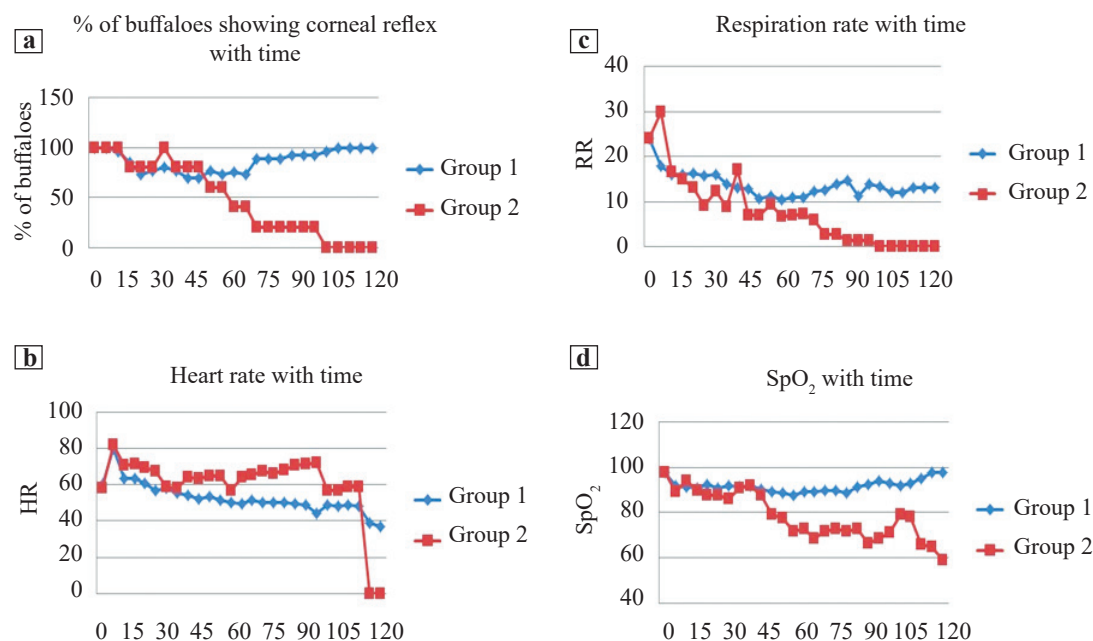


Fig. 1. Data depicted for Group 1 and Group 2.

buffaloes approached recovery (Supplementary Fig. 5).

Heart rate: A correlation between HR, RR and SpO_2 was found to be critical for assessing the condition of buffalo (Fig. 1b). With the removal of adhesions, the SpO_2 showed mild fall which was recovered with IPPV and air suction in Group 1 but a constant fall in SpO_2 with no respiration (but nostrils flaring) and increase in heart rate was an indication of in-efficient breathing and free air was suspected in pleural space. This could be a sign of danger if parameters do not improve and hence a close monitoring was required. The same situation was recorded when there was rupture of pleura during the breaking of adhesions. The SpO_2 showed constant decrease with increased HR and nostrils flaring but no movement of inspiratory valve in anaesthesia machine, showing inefficient respiration.

The HR in Group 2 was more throughout the surgery, as compared to Group 1. In Group 1, the HR showed gradual decrease and was stable around 38-40 min till recovery (Muchalambe *et al.* 2018). The HR was significantly ($p < 0.01$), higher in Group 2 in comparison to Group 1 after 70 min of anaesthesia, as a compensation to survive till a certain point after which there was sudden fall. This fall point was seen when the SpO_2 was critically low at around 60-70%. Barton *et al.* (1997) in a study on pathophysiology of pneumothorax in swine reported cardiovascular collapse at a SpO_2 of $\leq 50\%$. The HR and MAP remain relatively stable until a 500-mL (47% Total lung capacity) pneumothorax was established. After this point, the HR increased until cardiovascular collapse that occurred at approximately 900 mL ($>86\%$ Total lung capacity) of pneumothorax due to occlusion of venous return.

Respiration rate: The respiration rate decreased with time during surgery but again started increasing at recovery in Group 1, as compared to Group 2, where it kept decreasing and was significantly lower in Group 2 at 70 min

of anaesthesia ($p < 0.01$) (Fig. 1c). The initial decrease in respiration rate was supposed to be a respiratory depressant effect of propofol (Bufalari *et al.* 1998, Robertson *et al.* 1992) on afferent activity from carotid body. Therefore, a dual depression of central respiratory center and peripheral respiratory receptor activity could be expected during propofol anaesthesia.

Apnea: Apnea was seen in almost 80 to 100% buffaloes of Group 1 and 2, respectively, at the time when the hernia ring was clear of adhesions, irrespective of the intactness of pleura (Supplementary Fig. 6). But, in Group 2, the apnea persisted. In Group 1, the respiration recovered once the diaphragm was sutured and the suction was applied for the removal of free air from the pleural space.

SpO_2 : The SpO_2 was similar in both the groups at the start of anaesthesia, but, once the apnea started, in spite of the IPPV, the SpO_2 kept decreasing significantly ($p < 0.05$ and 0.01) in Group II at 65 to 80 min of anaesthesia in comparison to Group 1 where it improved with time (Fig. 1d).

Mean BP: The mean blood pressure of Group 2 was comparatively lower than the Group 1, from the start of the surgery and did not improve with time while, it gradually increased in Group 1 (Supplementary Fig. 7). The Mean BP was significantly ($p < 0.01$) lower at 70 min of anaesthesia. Reduction in arterial blood pressure has been attributed to stimulation of central α_2 adrenergic receptors at the brain stem and spinal cord (Drew 1976). With increase in the air in thoracic cavity, inhibition of sympathetic activity along with stimulation of α_2 adrenergic receptors at the brain stem and spinal cord occurs which decreases the arterial blood pressure.

Comparison of Peri-anaesthetic parameters in Group 3 and 4

SpO_2 : While comparing the buffaloes of Group 3 and

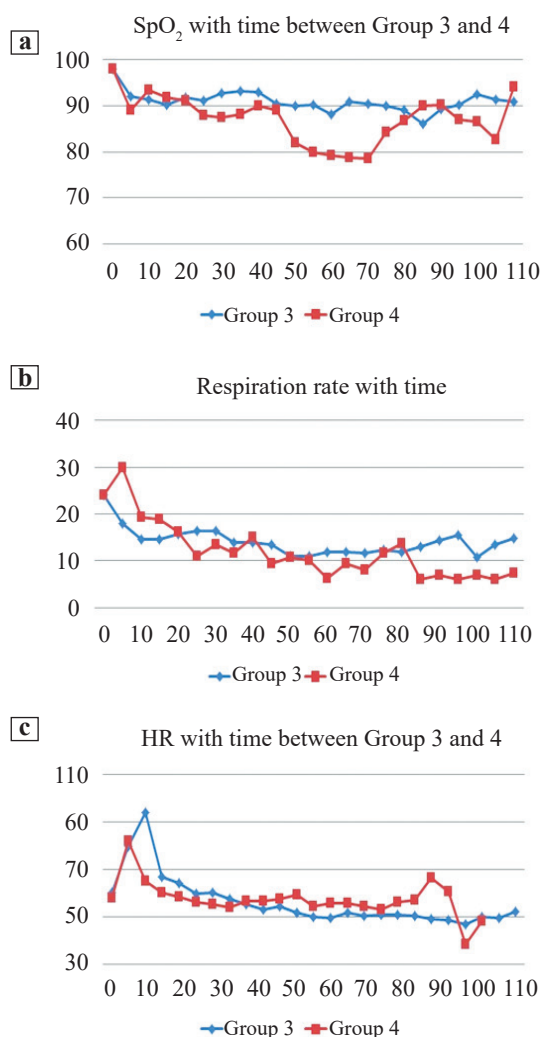


Fig. 2. Data depicted for Group 3 and Group 4.

4, the SpO₂ was always lower in the Group 4, especially at the time of rupture of pleura, it was significantly ($p < 0.01$) low (70-75 min) and improved with suction and IPPV (Fig. 2a). The low SpO₂ during pleura rupture might be due to the additional respiratory depression and hypoventilation. Suctioning removes the air from pleural cavity and thus helps in maintaining negative pressure within thorax resulting in expansion of lungs. Continuously decreasing SpO₂ level with the increasing air in thorax has been reported in literature (White *et al.* 1994). It was observed that at the time of rupture, the HR increased, but the SpO₂ decreased, with the buffalo making full efforts to take in more oxygen by increasing the HR and flaring the nostrils but due to ventilation-perfusion mismatch or decreased diffusion of gases between alveoli and the pulmonary capillary blood as in pleural rupture, was unsuccessful in maintaining the SpO₂. With the increasing pneumothorax, the HR increases as a result of catecholamine release and baroreceptor-mediated reflex. At excessive pneumothorax, there was occlusion of venous return resulting in CV collapse and death of the animal (Barton *et al.* 1997).

Respiration rate: The respiration rate, decreased in Group 4, but was constant in Group 3 which gradually increased

with recovery (Fig. 2b). The respiratory depression could also be due to hypoventilation state caused by the presence of air in the thorax, especially in case of pleural rupture. Air in pleural cavity causes loss of negative thoracic pressure resulting in restriction in lung expansion and hypoventilation and thus respiratory depression and apnea. Normal animal compensates this state by chest expansion but anaesthesia dampens this compensation.

HR: The HR was almost similar in Group 3 and 4, with HR increasing in Group 4 as a compensatory mechanism if the free air in the pleural cavity could not be removed, due to unapproachable multiple cavitation's (due to adhesions) leading to decrease in SpO₂ (Fig. 2c).

Apnea: More percentage of buffaloes showed apnea in Group 4 in comparison to Group 3 (Supplementary Fig. 8). Apnea in Group 4 might be due to respiratory depression caused by hypoventilation state as in rupture of pleura.

Recovery: The recovery was smooth in 11/26 (42.30%) buffaloes. Most of the buffaloes tried to stand up as soon as they were shifted to the sitting position from the operation trolley but showed imbalance. In Group 2, four buffaloes died on the operation table while one recovered from anaesthesia with laboured breathing and died after 40 min. Laboured breathing is correlated to presence of free air in the pleural space leading to in-efficient respiration. Rapid and smooth recovery might be due to a lower blood gas partition coefficient of isoflurane and better cardiovascular function perseverance and quicker elimination (Riazuddin *et al.* 2004). Use of propofol has also been reported to cause rapid, smooth induction and excitement free recovery in premedicated dogs (Bufalari *et al.* 1996).

The study recommended perioperative monitoring of eye reflexes, heart rate, respiration rate, and SpO₂ during diaphragmatic herniorrhaphy under general anaesthesia to take necessary precautions for the timely removal of free air from the pleural space. It also concluded that the integrity of the pleura plays an important role in the survival of buffaloes undergoing herniorrhaphy.

SUMMARY

The present study aimed to monitor the general anaesthesia (midazolam-propofol and isoflurane) in 31 buffaloes undergoing diaphragmatic herniorrhaphy in relation to pleural integrity and survivability. Various herniorrhaphy and peri-operative anaesthetic parameters of heart rate, respiration rate, SpO₂, apnea, corneal reflex, lacrimation, salivation, regurgitation and position of eyeball were recorded. The data was compared between the survivor (26/31=83.87%, Group 1) and the non-survivor group (Group 2) and between the buffaloes with intact pleura during herniorrhaphy (21/31= 67.75%, Group 3) and those with ruptured pleura (Group 4). Majority of the buffaloes (80%) in Group 2 had ruptured pleura during herniorrhaphy, while in Group 1, 76.92% had intact pleura. The corneal reflex was considered the most reliable manual parameter to assess the survival status of the buffalo in ventro-dorsal position and its absence was

considered alarming. The heart rate was significantly higher in Group 2 in comparison to Group 1 after breaking of hernia ring adhesions. The SpO_2 of Group 4 was always lower than in Group 3 and at the time of rupture of pleura it was significantly low but improved with suction and intermittent positive pressure ventilation in Group 1 buffaloes. The study recommended perioperative monitoring of eye reflexes, heart rate, respiration rate, and SpO_2 during diaphragmatic herniorrhaphy in buffaloes to take necessary precautions for the timely removal of free air from the pleural space. The integrity of the pleura plays an important role in the survival of buffaloes undergoing herniorrhaphy.

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