



Comparison of ketamine and propofol as maintenance agent for continuous intravenous infusion anaesthesia in water buffaloes

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ABSTRACT

The present study was conducted to compare the anaesthetic effects of ketamine and propofol as maintenance agents for continuous intravenous infusion anaesthesia in buffaloes. Clinically healthy adult male buffaloes (6), 2 to 3 year-old and weighing 290 to 325 kg, were used for repeated trials in 2 groups using medetomidine (2.5 µg/kg) and butorphanol (0.05 mg/kg) intravenously as preanaesthetics. Induction of anaesthesia was achieved with 5% thiopental sodium in both groups. Anaesthesia was maintained with continuous intravenous infusion of ketamine (1%) in group K and propofol (1%) in group P. The treatments were compared by clinicophysiological, cardiorespiratory and haemodynamic parameters. Excellent sedation, analgesia and muscular relaxation were observed in both groups. Depression of palpebral and corneal reflex was higher in group P than in group K. Downward rotation of eye ball for longer time was observed in group P than in K group. Required mean infusion rates of ketamine and propofol to maintain the adequate depth of anaesthesia in groups K and P were 0.16 ± 0.01 mg/kg/min and 0.05 ± 0.00 mg/kg/min, respectively. The values of recovery time, sternal recumbency time and standing time did not differ significantly between the groups. Difference in heart rate was not significant up to 60 min of anaesthesia but after 70 min onwards HR in group K was significantly higher compared to groups P. Respiratory rate in groups K remained significantly higher during the maintenance period than in group P. Decrease in rectal temperature was significantly higher in group P than in K group. Mean arterial pressure in groups K remained significantly lower than in group P. Central venous pressure did not differ significantly between the groups. Haemoglobin oxygen saturation (SpO₂) in group P remained significantly higher than in group K. Our results indicated that maintaining anaesthesia via continuous infusion of ketamine and propofol in buffaloes is a feasible, effective, and safe anaesthetic technique for surgical procedures of at least up to 2 h duration. Maintaining anaesthesia with propofol produced some depressive effects on cardiopulmonary parameters that were comparable to those associated with anaesthesia maintained by ketamine.

Key words: Anaesthesia, Buffalo, Continuous intravenous infusion, Ketamine, Medetomidine, Propofol

Inhalant anesthesia requires more expensive equipments and is unsuitable for surgical procedures under field condition. Total intravenous anesthesia (TIVA), which is the induction and maintenance of anesthesia with intravenous agents, bears potential advantages for field surgeons. TIVA also avoids some drawbacks of inhalant anesthesia, including operating room pollution and the cumbersome anesthetic equipments (Matthews 2007). Ketamine and propofol are injectable, short-acting, and rapidly metabolized agent chemically unrelated to barbiturates or other anesthetic agents. These agents are characterized by their rapid onset, short duration, rapid metabolism, lack of accumulation on rapid administration, some degrees of respiratory depression,

and a rapid smooth recovery from anesthesia (Sebel and Lowdon 1989). The use of ketamine and propofol as continuous intravenous infusion for maintenance of anesthesia has gained increasing popularity in small animal practice. However, the study of the merits of this technique in buffaloes is not available. The purpose of this study was to determine the quality of general anaesthesia in terms of degree of sedation, analgesia, muscular relaxation and degree of abolition of various reflexes during anaesthesia maintained with continuous intravenous infusion of ketamine and propofol in medetomidine-butorphanol premedicated buffaloes. The impact of these anaesthetic protocols on the cardio-respiratory and haemodynamic systems was also studied.

MATERIALS AND METHODS

Experimental animals and preparations: Clinically

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healthy male buffaloes (6), 2- to 3- year-old and weighing 290 to 325 kg were used in the present study. The animals were kept off feed for 48 h and water was withheld for 12 h prior to the start of the experiment. After aseptic preparations, a heparinised polythene catheter was introduced into the jugular vein through a 12 gauge hypodermic needle and passed up to the level of right atrium. This catheter was attached to the CVP saline manometer through a 3-way stop cock for recording of CVP. The cuff of the non-invasive blood pressure (NIBP) monitor was applied around the base of the tail for monitoring mean arterial blood pressure. The haemoglobin oxygen saturation was recorded by applying the sensor of pulse oxymeter at anal sphincter before and after premedication and on the tongue after induction of anaesthesia. The middle ear vein on the dorsal surface was cannulated with an 18 G intravenous catheter, and it was fixed on the ear with an adhesive tape for administration of drugs. The animals were left undisturbed for 30 min before recording of base values of all the parameters.

Experimental design: All the animals received 2 different treatments at 10 days intervals in groups K and P. In both groups sedation was accomplished by administration of medetomidine (2.5 µg/ kg) and butorphanol (0.05 mg/kg), intravenously and induction of anaesthesia was achieved by 5% thiopental sodium intravenously till effect. Maintenance of anaesthesia was done by continuous intravenous infusion of ketamine (1%) and propofol (1%) in groups K and P, respectively.

Drug administration: After 15 min of premedication, the sedated animals were induced by administration of half of the calculated induction dose of thiopental sodium, intravenously, over a period of approximately 30 sec. The animals were allowed to achieve lateral recumbency and additional dose was administered, if required, till the absence of animal's response to noxious stimulus (by applying and closing a towel clamp completely on the last coccygeal vertebra). The infusion of ketamine (1%) in group K and propofol (1%) in group P, was started immediately and adjusted to maintain an adequate anaesthetic plane as determined by response to noxious stimulus.

Observations

Required doses of maintenance agents: Infusion rates (mg/ kg/min) of ketamine and propofol, required for maintenance of anaesthesia were calculated after the completion of each trial.

Reflexes: Degree of abolition of palpebral and corneal reflexes was recorded at different intervals in the animals of different groups. The response of these reflexes was graded on a (-) to (+++++) scoring scale where: (-), completely abolished; (+), mild response; (++) , moderate response; (+++) , good response; (++++), excellent response.

Muscular relaxation: Muscle relaxation was observed in the muscles of abdomen, legs and jaws. The muscular

relaxation was graded in a 1–4 scoring scale: 1 (no relaxation) , tightly closed jaws and stiff limbs and tightly placed abdominal muscles; 2 (mild relaxation) , moderate resistance to opening of jaws and bending of limbs and pressing of abdomen; 3 (moderate relaxation), mild resistance to opening of jaws and bending of limbs and pressing of abdomen; 4 (excellent relaxation), no resistance to opening of jaws and bending of limbs and flaccid abdomen.

Extent of salivation: The extent of salivation at different intervals of anaesthesia was also recorded. The extent of salivation was graded on a (-) to (+++) scoring scale: (-), absent; (+), mild; (++) , moderate; (+++) , profuse.

Recovery time (RT): The time from discontinuation of halothane and the first spontaneous movement of any body part was considered as recovery time.

Sternal recumbency time (SRT): The time from discontinuation of halothane to the spontaneous regaining of sternal recumbency was considered as sternal recumbency time.

Standing time (ST): The time from discontinuation of halothane to spontaneous regaining of standing position was considered as standing time.

Heart rate (HR) (beats/min), respiratory rate (RR) (breaths/min) and rectal temperature (RT)(°C): These were recorded at 0 (base line), 5, 10, 15, 20, 30, 40, 50, 60, 70, 80, 90, 100, 110 and 120 min of anaesthesia.

Mean arterial pressure (MAP) (mm Hg), central venous pressure (CVP) (cm H₂O) and arterial haemoglobin oxygen saturation SpO₂ (%) were recorded at 0 (base line), 5, 10, 15, 20, 30, 40, 50, 60, 70, 80, 90, 100, 110 and 120 min of anaesthesia.

Analysis of variance (ANOVA) and Duncan's multiple range test (DMRT) were used to compare the means at different time intervals among different groups. Paired 't' test was used to compare the mean values at different intervals with their base values in each group (Snedecor and Cochran 1980). In each analysis, a value of P<0.05 or P<0.01 was considered statistically significant.

RESULTS AND DISCUSSION

The present study seems to be the first to compare continuous intravenous infusion anaesthesia using ketamine and propofol in buffaloes. The dose of medetomidine used was lower than those used by others (Pawde *et al.* 1996) because it was used with butorphanol. Muir III *et al.* (1999) considered the combination of medetomidine and butorphanol better for optimal sedation, analgesia and muscular relaxation as it caused subsequent reduction in doses of other anaesthetics needed for the induction and maintenance of anaesthesia.

Required mean infusion rates of ketamine and propofol to maintain the adequate depth of anaesthesia in groups K and P were 0.16±0.01 mg/kg/min and 0.05±0.00 mg/kg/min, respectively. Reduction in the induction dose of thiopental

was recorded in both groups as the usual dose of thiopental in large ruminants is around 8–10 mg/kg. The co-administration of alpha-2 agonist with opioid has been reported to decrease the anaesthetic requirement (Tranquilli and Maze 1993). Synergism between medetomidine-butorphanol and thiopental might have played an important role in reducing the induction doses of thiopental in the present study. The required infusion rate of propofol to maintain adequate plane of anaesthesia was 0.05 ± 0.00 mg/kg/min in the present study. Continuous intravenous infusion of 0.30 mg/kg/min of propofol provided satisfactory anaesthesia in the pregnant ewes (Alone *et al.* 1993, Gaynor *et al.* 1996) and 0.45 mg/kg/min of propofol in non-pregnant sheep (Runciman *et al.* 1990). However, a higher propofol infusion rate of 0.52 ± 0.11 mg/kg/min maintained the goats at an acceptable plane of anaesthesia after detomidine premedication and propofol induction (Carroll *et al.* 1998). The difference in the infusion rates of propofol between the present and previous studies might be due to species difference and nature and dose of preanaesthetics and induction agents used.

Excellent muscle relaxation was observed in all the groups. Median $\pm$ SE (range) muscle relaxation score was 4 ± 0.51 (3–4) in both groups. In both groups 4 animals had excellent muscle relaxation (score 4) and 2 animals from each group had good muscular relaxation (score 3). Propofol in the present study produced excellent muscular relaxation and no myoclonus was reported in any of the animals. Ketamine, however, does not possess muscle relaxation property but good to excellent relaxation in animals of ketamine group might be due to long lasting muscle relaxation effect of medetomidine or midazolam.

In the animals of group K the palpebral reflex depressed mildly after 5 min of medetomidine and butorphanol administration but moderate response persisted up to 15 min of premedication. After anaesthetic induction palpebral reflex was completely abolished for 30 min, but later on moderate response was observed, up to the end of the observation period. In the animals of groups P the palpebral reflex was moderately depressed up to 15 min, after premedication and remained absent during rest of the observation period. Comparison between the groups revealed that the depression of palpebral reflex was higher in the animals of group P than in group K. In both groups the corneal reflex was depressed and showed good to moderate response after administration of preanaesthetics. However, corneal reflex was abolished completely after administration of thiopental sodium in both groups. For rest of the observation period it remained mildly depressed in group K and moderately depressed in group P. During ketamine anaesthesia in group K the palpebral and corneal reflexes did not completely abolish but showed moderate to good response. Muir *et al.* (1977) also reported similar observations after xylazine and ketamine anaesthesia in horses. The characteristics of ketamine anaesthesia are

quite unlike to those which are generally observed after the administration of inhalational and barbiturate anaesthetic agents. The latter agents produce total suppression of the patient's reflexes, but after ketamine, the palpebral reflex is brisk, nystagmus is frequently observed and the animal may move its limbs but such movements are not associated with painful stimuli and there is marked degree of analgesia (Waterman *et al.* 1981). Similarly, palpebral and corneal reflexes are mildly active during ketamine anaesthesia in cattle (Wright 1982) and goats (Tadmor and Zukerman 1981). Propofol infusion in the animals of group P produced almost complete abolition of palpebral and corneal reflexes.

Eye ball position during general anaesthesia is a reliable indicator of the depth of anaesthesia in ruminants (Reibald 2007). The eye ball remained in central position during sedation in all the animals of both groups. After administration of thiopental, the eye ball rotated ventro-medially in all the animals. Similar findings were reported after thiopental administration in bovines (Kaur and Singh 2004), and in dogs (Singh 2007). Whereas, during maintenance of anaesthesia the eye ball remained in central position for most of the period in the animals of group K as the effect of thiopental might have weaned off after 10–15 min. Similarly, no rotation of eye ball during ketamine anaesthesia was reported in bovines (Kaur and Singh 2004) and in dogs (Singh 2007). The downward rotation of eye ball during maintenance of anaesthesia with propofol in the animals of group P in this study is in accordance to the findings of Hughes and Nolan (1999) in dogs and Rugh *et al.* (1985) in cattle.

Mild to moderate salivation was observed after 5 to 10 min of premedication in both groups, which persisted until the end of observation period in group K, whereas, in group P only mild salivation persisted up to 70 min, except in 2 animals, that showed mild to profuse salivation. The extent of salivation was higher in the animals of group K than that of group P. Excessive salivation after alpha-2 agonists was reported in goats even with prior atropinisation (Chitale *et al.* 1999). Salivation during maintenance in both groups could be due to decreased swallowing reflex (Kokkonen and Eriksson 1987) and down-head position of the animal. Regurgitation, a frequent complication during general anaesthesia in ruminants (Reid *et al.* 1993) was not seen in the animals of present study. It might primarily be due to fasting of animals for 48 h prior to start of the experiment and correct positioning of the animals during anaesthesia as the caudal cervical and anterior thoracic region of the animal was placed higher than any other body region. Evacuation of ruminal content and subsequent fasting for 2 days for major surgery of longer duration in buffaloes were recommended by Peshin *et al.* (1987), however, in the present study proper positioning and fasting of animals could very well prevent regurgitation.

The median $\pm$ SD (range) values of RET observed in groups

K and P groups were 10 ± 3.39 (5–15) and 4.5 ± 3.14 (1–10) min, respectively, which did not differ significantly ($P > 0.05$). The median $\pm$ SD (range) values of SRT observed in K and P groups were 25 ± 7.13 (14–35) and 14 ± 4.88 (6–20) min, respectively. No significant difference was noted in SRT between the groups. The median $\pm$ SD (range) values of ST observed in K and P groups were 35 ± 11.29 (30–60) and 16.4 ± 6.71 (8–27) min, respectively. No significant ($P > 0.05$) difference in ST was observed between the 2 groups. Animals of group P took least time to recover, to resume sternal recumbency and to stand on their feet than that of group K, however, it did not differ significantly between the groups. Rapid recovery after propofol anaesthesia was reported in goats (Prassinis *et al.* 2005). Though data regarding pharmacokinetics of propofol in buffaloes is not available but in earlier studies in goats pharmacokinetics of propofol showed that it is extensively redistributed from blood to tissue (Reid *et al.* 1993). Propofol anaesthesia is reported with extubation time less than 10 min and time to standing less than 30 min in both premedicated and unpremedicated goats (Carroll *et al.* 1998, Prassinis *et al.* 2005). Our observations also conformed to the findings of Lin *et al.* (1997), who reported faster and complete return of muscle strength in sheep maintained with propofol infusion (0.49 ± 0.20 mg/kg/min) as compared to those maintained with halothane.

Medetomidine and butorphanol resulted in a significant decrease in heart rate immediately after their administration in both groups. In group K at 20 min a more significant ($P < 0.01$) decrease in HR was observed. After 30 min, HR improved and returned around the base value at the end of observation period. In group P, HR decreased up to 20 min. Later HR improved to some extent, but remained lower in comparison to the base line. Comparison between the groups showed that HR in group K was significantly higher in comparison to groups P after 70 min (Fig. 1).

Higher values of heart rate during ketamine infusion in comparison to post-sedation values in the present study could be attributed to its sympathomimetic action mediated within

the CNS, inhibition of catecholamine re-uptake by peripheral sympathetic nerve endings and the subsequent effects of catecholamines on the myocardium (Lin 2007). During a ketamine-based TIVA, a significantly higher heart rate was reported in a group of dogs receiving ketamine compared to a group of dogs receiving propofol (Hellebrakers *et al.* 1998). An increased HR during propofol infusion was also recorded in the animals of group P, however, the values remained lower than the base line. The positive chronotropic effect of propofol in medetomidine premedicated buffaloes was reported, which may be attributed to an indirect central effect of propofol on heart muscles (Vainio 1991). Significant increase in the heart rate was also observed during propofol anaesthesia in sheep (Lin *et al.* 1997) and goats (Amarpal *et al.* 2002). In another study, cardiopulmonary variables were reported to be stable during maintenance of anaesthesia with intravenous infusion rates of 0.15, 0.3 and 0.45 mg/kg/min of propofol for 2 h and it did not produce any adverse cardiopulmonary effects in mechanically ventilated sheep (Alon *et al.* 1993).

In group K, RR decreased nonsignificantly ($P > 0.05$) after preanaesthetic administration and remained so up to 30 min. Thereafter, RR increased gradually with a significant ($P < 0.01$) increase between 90 and 120 min. In group P, RR decreased significantly ($P < 0.01$) at 5 and 15 min, which improved after the infusion of propofol and remained slightly below the base line until the end of observation period. Comparison between the groups revealed no significant difference in RR at most of the intervals (Fig. 2).

Increase in respiratory rate was recorded during maintenance of anaesthesia in the animals of K group, which might be due to some degree of hyperventilation induced by ketamine, as reported in calves (Waterman 1981). In the animals of group P the respiratory rate remained decreased in comparison to the base line values throughout the period of anaesthesia, which might be attributed to the respiratory depressant effect of propofol. Apnoea was reported to be a common finding with intravenous administration of propofol anaesthesia in domestic animals (Morgan and Legge 1989).

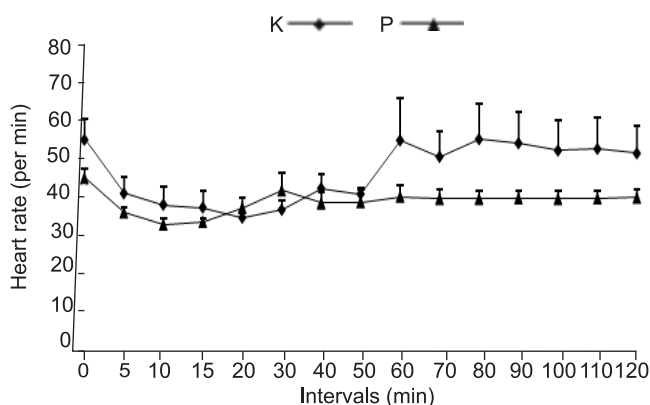


Fig. 1. Heart rate (beats/min) at different time intervals in K and P groups.

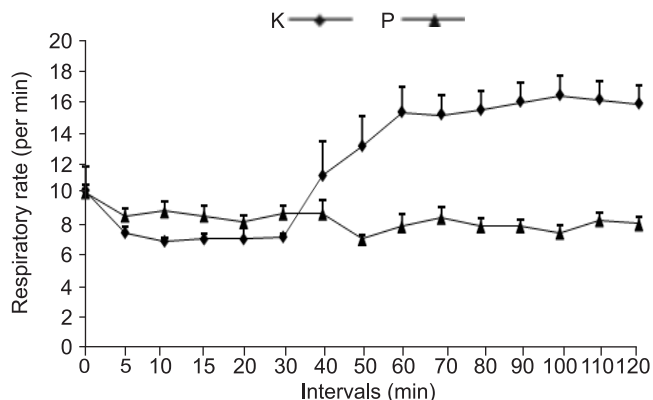


Fig. 2. Respiratory rate (breaths/min) at different time intervals in groups K and P.

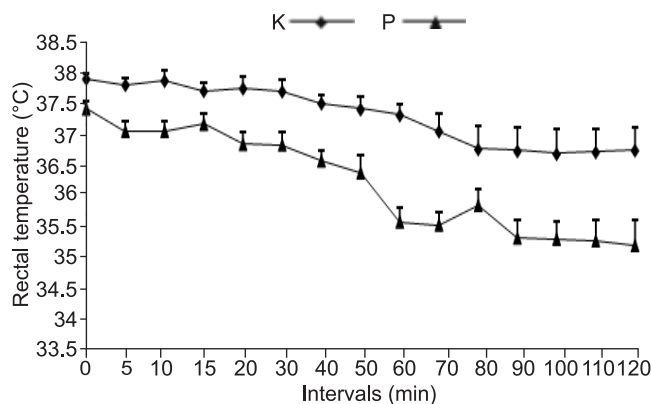


Fig. 3. Rectal temperature (°C) at different time intervals in groups K and P.

However, apnoea was not a common finding in this study except in 2 cases, where a short period of apnoea was observed, which might be attributed to rapid rate of administration of the drug.

In group K, RT decreased significantly ($P < 0.01$) from 40 min up to the end of observation period. However, a less significant ($P < 0.05$) decrease in RT was observed between 50 and 120 min. Significant ($P < 0.01$) hypothermia was recorded in the animals of group P after 20 min of premedication, which remained so after induction and during maintenance of anaesthesia. Comparison between the groups revealed that decrease in RT in group P was significantly ($P < 0.05$) greater than in K group at most of the intervals (Fig. 3). Decrease in rectal temperature during sedation and maintenance period in the present study might be due to generalized sedation and consequent decrease in metabolic rate. RT also reduced during propofol anaesthesia in goats (Amarpal *et al.* 2002) and in dogs (Ajadi *et al.* 2007).

Group K recorded a significant ($P < 0.01$) decrease in MAP from 5 to 10 min of medetomidine and butorphanol administration and remained decreased significantly ($P < 0.05$) after induction up to 70 min. It improved later on but remained nonsignificantly decreased ($P > 0.05$) up to 120 min. In group P, MAP decreased nonsignificantly ($P > 0.05$) at 5

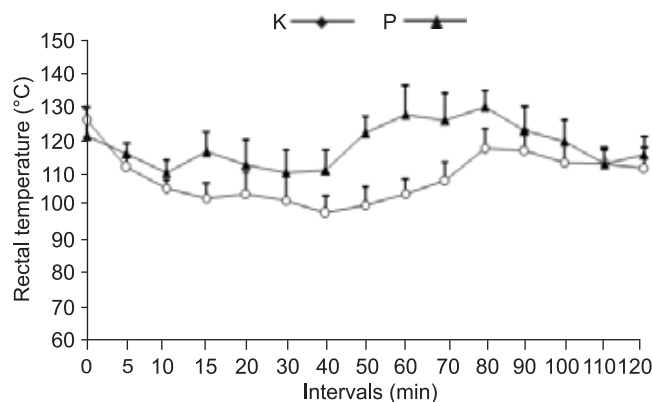


Fig. 4. Mean arterial pressure (mm Hg) at different time intervals in groups K and P.

min after premedication up to 40 min. Thereafter, it increased nonsignificantly ($P > 0.05$) up to 90 min (Fig. 4).

In group K, MAP remained on lower side throughout the period of observation but it moderated the hypotensive effect of medetomidine. An increase in the arterial blood pressure after ketamine administration could be due to the selective positive inotropic influence on heart muscles or reflexogenic autonomic nervous system changes (Adams *et al.* 1976). Ketamine increased the blood pressure and heart rate in animals (Lin 2007). Mean arterial pressure decreased after medetomidine and butorphanol administration in group P. However, it did not decrease further during propofol infusion and stayed just below the base value. A decrease in arterial pressure after propofol administration was commonly reported in domestic animals and was found associated with arterial and venous vasodilatation and decreased contractility of the heart (Robinson *et al.* 1997).

In group K a significant ($P < 0.01$) increase in CVP was recorded immediately after premedication till the end. However, maximum increase was observed after 15 min of premedication, which decreased a little after induction and remained decreased till the end but was significantly ($P < 0.05$) higher than the base line. Group P recorded a significant ($P < 0.05$) increase in CVP after 5 min of premedication up to 120 min. However, the maximal increase was observed at 30 min and thereafter, it followed a decreasing trend towards the end of observation period. Comparison revealed that CVP did not show any significant ($P < 0.05$) difference at any time interval of observation period between groups P and K (Fig. 5). Similar findings were reported after thiopentone administration in buffaloes (Singh *et al.* 1980). CVP, however, showed a decline after the start of maintenance of anaesthesia but it remained significantly higher than the base values in all the 3 groups. Continued maintenance of CVP at higher level in these groups might possibly be due to depressive influence of medetomidine-butorphanol on the heart that gradually subsided with the elimination of the drugs as also reported by Kinjavdekar *et al.* (2005).

In group K a significant ($P < 0.01$) decrease in SpO_2 was

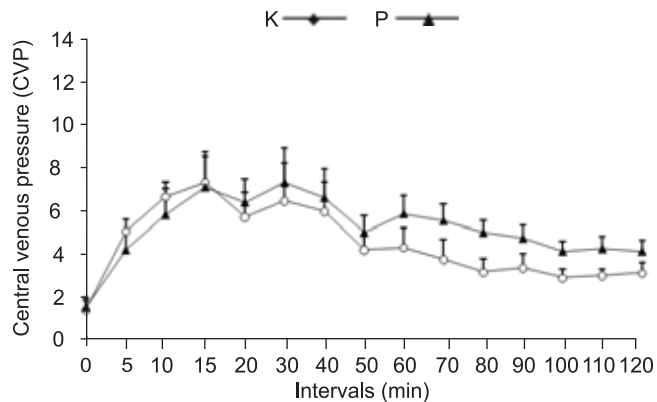


Fig. 5. Central venous pressure (cm H₂O) at different time intervals in K and P groups.

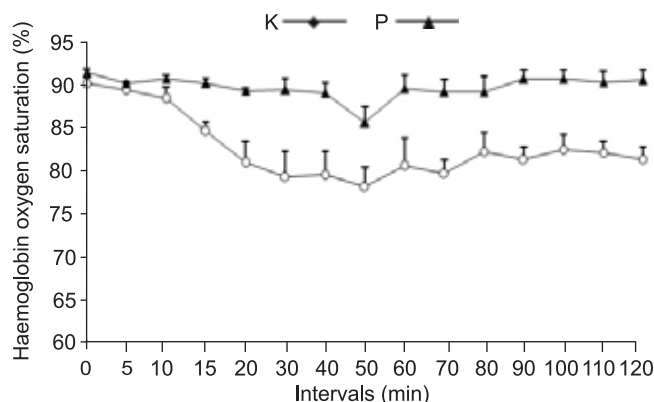


Fig. 6. Haemoglobin oxygen saturation (%) at different time intervals in groups K and P.

recorded from 15 min up to 120 min, with minimal values at 50 min. In group P, SpO_2 recorded a significant ($P < 0.05$) decrease at 15 and 20 min which remained nonsignificantly ($P > 0.05$) lower than the baseline during rest of the observation period. On comparison with group K it was observed that SpO_2 remained significantly ($P < 0.05$) higher in group P than in group K for the entire observation period (Fig. 6). Decrease in SpO_2 values were possibly due to certain degree of respiratory depression in all groups. Low SpO_2 values with medetomidine-ketamine anaesthesia were reported in rabbits (Grint and Murison 2008). Similar findings were reported during propofol infusion in dogs (Beths *et al.* 2001). The changes in SpO_2 during ketamine or propofol infusion were inversely proportional to the rate of administration of the drugs and could be adjusted easily by changing the rate of infusion. Ketamine and propofol infusion cause significant respiratory depression with decrease in all measures of ventilation in animals (Gomez-Villamandos 2006).

However, Carroll *et al.* (1998) did not report any sign of hypoxemia in goats maintained on propofol infusion as they observed no change in SpO_2 and SaO_2 .

Our results indicated that maintaining anaesthesia via continuous infusion of ketamine and propofol in buffaloes is a feasible, effective, and safe anaesthetic technique for surgical procedures of at least up to 2 h duration. Maintaining anaesthesia using propofol produced some depressive effects on cardiopulmonary parameters that were comparable to those associated with anaesthesia maintained by ketamine.

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REFERENCES

- Adams H R, Taske R H and Merser H D. 1976. Anaesthetic antibiotic relationships. *Journal of American Veterinary Medical Association* **168**: 409–12.
- Ajadi R A, Adetunji A and Olaniyan O S. 2007. A clinical trial of

propofol infusion in xylazine premedicated dogs undergoing laparogastrotomy. *Israel Journal of Veterinary Medicine* **62**(2): 56–57.

- Alon E, Ball R H and Gillie M H. 1993. Effects of propofol and thiopental on maternal and fetal cardiovascular and acid base variables in the pregnant ewe. *Anaesthesiology* **78**: 562–76.
- Amarpal, Kinjavdekar P, Aithal H P, Pathak R, Singh V and Pratap K. 2002. Effect of xylazine in medetomidine on propofol anaesthesia in goats. *Indian Journal of Animal Sciences* **72**: 565–66.
- Beths T, Glen J, Reid J, Monterro A and Nolan A M. 2001. Evaluation and optimization of a target controlled infusion system for administered propofol to dogs as part of total intravenous anaesthetic technique during dental surgery. *Veterinary Record* **148**: 198–203.
- Carroll G L, Hooper R N, Slater M R, Hartsfield, S M and Matthews N S. 1998. Detomidine-Butorphanol-Propofol for carotid artery Translocation and castration or ovarioectomy in goats. *Veterinary Surgery* **27**: 75–82.
- Chitale D, Pratap K, Amarpal, Gupta O P, Aithal H P and Singh G R. 1999. Observations on some clinical aspects of alpha-2 agonists with diazepam as preanaesthetic to ketamine anaesthesia in goats. *Indian Veterinary Journal* **76**: 112–14.
- Gomez-Villamandos R J, Palacois C, Benitez A, Granados M M, Dominguez J M, Lopez I, Ruiz I, Agullera E and Santisteban J M. 2006. Dexmedetomidine or medetomidine premedication before propofol-desflurane anaesthesia in dogs. *Journal of Veterinary Pharmacology and Therapeutics* **29**(3): 157–63.
- Grint N J and Murison P J. 2008. A comparison of ketamine-midazolam and ketamine-medetomidine combinations for induction of anaesthesia in rabbits. *Veterinary Anaesthesia and Analgesia* **35**: 113–21.
- Hellebrekers L J, van H H, Hird J F, Rosenhagen C U, Sap R and Vainio O. 1998. Clinical efficacy and safety of propofol or ketamine anaesthesia in dogs premedicated with medetomidine. *Veterinary Record* **142**: 631–34.
- Hughes J and Nolan A. 1999. TIVA in greyhounds: Pharmacokinetics of propofol and fentanyl- a preliminary study. *Veterinary Surgery* **28**: 513–24.
- Kaur A and Singh S S. 2004. Clinical effects of midazolam-ketamine and midazolam thiopentone anaesthesia in bovines. *Indian Journal of Veterinary Surgery* **25**(2): 80–82.
- Kinjavdekar P, Singh G R, Amarpal, Aithal H P, Pawde A M and Bist G S. 2005. Haemodynamic effects of spinally administered ketamine and its combination with xylazine or medetomidine in goats. *Indian Journal of Veterinary Surgery* **26**(2): 91–95.
- Kokkonen U M and Eriksson L. 1987. Cardiovascular and allied actions of xylazine and atropine in unanaesthetized goats. *Journal of Veterinary Pharmacology and Therapeutics* **10**: 11–16.
- Lin H C, Purohit R C and Powe T A. 1997. Anaesthesia in sheep with propofol or with xylazine-ketamine followed by halothane. *Veterinary Surgery* **26**: 247–52.
- Lin H C. 2007. Dissociative Anaesthetics. *Veterinary Anaesthesia and Analgesia*. 4th edn, pp 301–353. (Eds) Tranquilli W J, Thurmon J C and Grimm K A Lumb & Jones' Blackwell Publishing Ltd, Oxford.
- Matthews N S. 2007. Inhalant anaesthetics. *BSAVA Manual of Canine and Feline Anaesthesia and Analgesia*. 2nd edn, pp 150–55. (Eds) Seymour C and Duke-Novakowski T. British Small

- Animal Veterinary Association, Gloucester.
- Morgan D W T and Legge K. 1989. Clinical evaluation of propofol as an intravenous anaesthetic agent in cats and dogs. *Veterinary Record* **124**: 31–33.
- Muir III W W, Ford J L, Karpa G E, Harrison E E and Gadawski J E. 1999. Effects of intramuscular administration of low doses of medetomidine and medetomidine-butorphanol in middle aged and old dogs. *Journal of American Veterinary Medical Association* **8**: 1116–20.
- Muir W W, Skarda R T and Milne D W. 1977. Evaluation of xylazine-ketamine hydrochloride for anaesthesia of horses. *American Journal of Veterinary Research* **38**: 195–200.
- Pawde A M, Amarpal, Singh G R and Kumar N. 1996. Clinicophysiological effects of medetomidine in female goats. *Small Ruminant Research* **20**: 95–98.
- Peshin P K, Krishnamurthy K, Singh K, Nassimi M N and Nigam J M. 1987. Haemodynamic and blood gas changes in buffaloes (*Bubalus bubalis*) in the supine position in the supine position following thiopentone anaesthesia with premedication. *Veterinary Research Communications* **11**: 1–7.
- Prassinis N N, Galatos A D and Raptopoulos D. 2005. A comparison of propofol, thiopental or ketamine as induction agents in goats. *Veterinary Anaesthesia and Analgesia* **32**(5): 289–96.
- Reibald T W. 2007. Ruminants. *Lumb and Jones' Veterinary Anaesthesia and Analgesia*, 4th edn, pp 740. (Eds) William J Tranquilli, John, Thurmon C and Kurt A Grimm. Blackwell Publishing Ltd, USA.
- Reid J, Nolan A M and Welch E. 1993. Propofol as an induction agent in the goat: A pharmacokinetic study. *Journal of Veterinary Pharmacology and Therapeutics* **16**: 488–93.
- Robinson B J, Ebert T J and O'Brien T J. 1997. Mechanisms whereby propofol mediates peripheral vasodilation in humans. *Anesthesiology* **86**: 64–72.
- Rugh K S, Zinn G M, Paterson J A and Thome J G. 1985. Inhalant anaesthetics in cattle. *Laboratory Animal Science* **35**: 178–81.
- Runciman W B, Mather L E and Selby D G. 1990 Cardiovascular effects of propofol and thiopentone anaesthesia in sheep. *British Journal of Anaesthesia* **65**: 353–59.
- Sebel P S and Lowdon J D. 1989. Propofol: a new intravenous anesthetic. *Anesthesiology* **71**: 260–77.
- Singh J, Mirakhur K K, Sobti V K and Kohli R N. 1980. Haemodynamics, blood gas and metabolic alterations during thiopentone anaesthesia in buffaloes. *Zentralblatt Veterinärmedizin A* **27**: 230.
- Singh S. 2007. 'Evaluation of thiopental-ketamine/propofol with premedicants ie. Atropine, diazepam/midazolam-butorphanol in canine orthopaedic patients.' Dissertation, Indian Veterinary Research Institute, India.
- Snedecor G W and Cochran W G. 1980. *Statistical Methods*. 9th edn. Iowa state university, Press, USA.
- Tadmor A and Zukerman I. 1981. The use of ketamine HCL for endotracheal intubation in goats. *Australian Veterinary Journal* **57**: 303–04.
- Tranquilli W J and Maze M. 1993. Clinical pharmacology and use of alpha-2 agonist in veterinary anaesthesia. *Anaesthesia and Pharmacology Review* **1**: 297–309.
- Vainio O. 1991. Propofol infusion anaesthesia in dogs premedicated with medetomidine. *Journal of Veterinary Anaesthesia* **18**: 35–37.
- Waterman A E. 1981. Preliminary observations on the use of a combination of xylazine and ketamine hydrochloride in calves. *Veterinary Record* **109**: 464–67.
- Wright M. 1982. Pharmacologic effects of ketamine and its use in veterinary medicine. *Journal of American Veterinary Medical Association* **180**: 1462–69.