

GENERAL ANAESTHESIA IN CAMELS: A SHORT REVIEW

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ABSTRACT

General anaesthesia is widely used as a method of chemical restraint for various diagnostic procedures as well as for both major and minor surgical interventions. In camelid practice, general anaesthesia may be required for several clinical procedures, including exploratory laparotomy in colicky calves (crias), castration of adult llamas, and surgical exploration of fistulous tracts. However, anaesthetic management of camelids can present challenges because of their unique anatomical and physiological characteristics, stress responses, and airway management considerations. Similar to other domestic species, general anaesthesia in both New World camelids (llamas and alpacas) and Old World camelids (camels) may be induced and maintained using injectable anaesthetic agents, inhalational anaesthetics, or a combination of both. Several drugs including xylazine, guaifenesin, ketamine, thiopental, halothane, and isoflurane have been widely used for sedation and general anaesthesia in camelids. Recent studies have further evaluated the physiological responses and clinical outcomes associated with various anaesthetic protocols, including total intravenous anaesthesia and multimodal analgesia in camelids undergoing surgical procedures. Several classes of drugs are used as premedicants in camelids, including α_2 -adrenergic agonists, opioids, tranquilizers, and anticholinergic agents. Other α_2 -adrenergic agonists such as romifidine, medetomidine, and dexmedetomidine have also been investigated for sedation and premedication in camelids. Butorphanol, a mixed agonist-antagonist opioid, is commonly used in camelids as analgesics and are frequently combined with α_2 -agonists to enhance analgesia and improve sedation. Total intravenous anaesthesia (TIVA) represents a practical and effective alternative to inhalational anaesthesia. Intravenous anaesthetic protocols are commonly used for short to moderate duration procedures such as castration, wound management, orthopedic interventions, and exploratory surgery. Appropriate drug selection, dosage, and monitoring are essential to minimise complications and ensure safe anaesthetic management in camels.

Key words: Anticholinergic agents, camelids, general anaesthesia, tranquilizers, α_2 -adrenergic agonists

Successful anaesthetic management of camelids depends on a thorough understanding of basic anaesthetic principles as well as detailed knowledge of the anatomy and physiology of these species. Appropriate anaesthetic planning is essential to ensure safe induction, maintenance, and recovery in camelids undergoing surgical or diagnostic procedures. Recovery from anaesthesia in camelids is generally smooth, and animals are typically able to stand shortly after tracheal extubation (Fowler, 2010). General anaesthesia is widely used as a method of chemical restraint for various diagnostic procedures as well as for both major and minor surgical interventions. Indeed, the development of modern surgical techniques has been made possible largely through advances in anaesthesia, which remains one of the most important achievements in

medical science (Thurmon *et al*, 1996 and Tranquilli *et al*, 2015).

In camelid practice, general anaesthesia may be required for several clinical procedures, including exploratory laparotomy in colicky calves (crias), castration of adult llamas, and surgical exploration of fistulous tracts. However, anaesthetic management of camelids can present challenges because of their unique anatomical and physiological characteristics, stress responses, and airway management considerations. Additionally, camels weighing more than 150 kg body weight often require specialised large-animal anaesthetic equipment for administration of inhalational anaesthetic agents. Therefore, a variety of anaesthetic techniques have been developed and described to ensure safe and effective anaesthesia in camelids.

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Similar to other domestic species, general anaesthesia in both New World camelids (llamas and alpacas) and Old World camelids (camels) may be induced and maintained using injectable anaesthetic agents, inhalational anaesthetics, or a combination of both. Several drugs including xylazine, guaifenesin, ketamine, thiopental, halothane, and isoflurane have been widely used for sedation and general anaesthesia in camelids. Almubarak (2013) found that intravenous butorphanol produced short-term satisfactory analgesia, coupled with mild sedation and minimal side effects in camels. Recent studies have further evaluated the physiological responses and clinical outcomes associated with various anaesthetic protocols, including total intravenous anaesthesia and multimodal analgesia in camelids undergoing surgical procedures (Goicochea-Vargas *et al*, 2024). Recent research has also evaluated epidural α_2 -agonists such as romifidine and xylazine, which produce effective sedation and prolonged analgesia in camels undergoing standing surgery (Hamed *et al*, 2025). Dexmedetomidine was established as an effective α_2 -adrenergic agonist sedative for handling and minor surgical interventions and it was also used in combination with butorphanol and ketamine in camels (Nath *et al*, 2023; Nath *et al*, 2024). Contemporary veterinary literature has also expanded knowledge on camelid anaesthesia and perioperative management through updated clinical texts and practical veterinary guidelines (Niehaus, 2022; Anderson *et al*, 2023). Because camelids possess unique anatomical and physiological features, including compartmentalised stomachs and susceptibility to regurgitation, careful anaesthetic planning is essential.

Therefore, the purpose of this review is to expand the existing body of knowledge by summarising recent advances and relevant literature concerning anaesthetic management in camelids, particularly focusing on llamas, alpacas, and camels.

Premedication Protocols in Camelids

Premedication is an important component of balanced anaesthesia in camelids as it helps reduce stress and anxiety, facilitates handling and restraint, and decreases the dose of anaesthetic agents required for induction and maintenance. Appropriate premedication also improves the quality of induction and recovery while providing varying degrees of analgesia and muscle relaxation (Grimm *et al*, 2015). Camelids are generally sensitive to stress and handling; therefore, adequate sedation

prior to anaesthesia is recommended to minimise catecholamine release and prevent complications during induction.

Several classes of drugs are used as premedicants in camelids, including α_2 -adrenergic agonists, opioids, tranquilisers, and anticholinergic agents (Ali *et al*, 1989; Khalil *et al*, 2019; Valverde, 2016) (Fig 1). Among these, α_2 -adrenergic agonists are most frequently used because of their potent sedative, analgesic, and muscle-relaxant effects. Xylazine is one of the most commonly used sedatives in camelids and has been reported to produce reliable sedation and moderate analgesia (Peshin *et al*, 1980). Typical doses range from 0.1–0.4 mg/kg administered intravenously or intramuscularly, depending on the level of sedation required (Fowler, 2010). However, xylazine may cause dose-dependent cardiovascular depression, including bradycardia and decreased cardiac output, and therefore careful monitoring is required. Xylazine sedation has also been used for liver biopsy in camel (Bucci *et al*, 1982).

Other α_2 -adrenergic agonists such as romifidine, medetomidine, and dexmedetomidine have also been investigated for sedation and premedication in camelids. These agents generally produce longer and more profound sedation with improved analgesia compared with xylazine. Romifidine has been reported to provide effective sedation with minimal ataxia, while dexmedetomidine has gained increasing attention because of its high selectivity for α_2 -receptors and its ability to produce reliable sedation and analgesia in camelids (Alsobayil *et al*, 2016; Bani-Ismail, 2016).

Opioid analgesics are frequently combined with α_2 -agonists to enhance analgesia and improve sedation. Butorphanol, a mixed agonist–antagonist opioid, is commonly used in camelids at doses of 0.02–0.05 mg/kg IV or IM. The combination of xylazine and butorphanol produces synergistic sedative and analgesic effects and is widely used for minor surgical procedures and diagnostic interventions (Anderson *et al*, 2018).

Tranquilisers such as acepromazine may also be used in camelids to reduce anxiety and facilitate handling. Acepromazine produces mild sedation through dopamine receptor blockade and peripheral vasodilation. However, its use should be cautious because it may cause hypotension and prolonged sedation, particularly in debilitated animals. Ali *et al* (1989) used four tranquilisers (propionyl promazine, xylazine, acepromazine and chlorpromazine) in

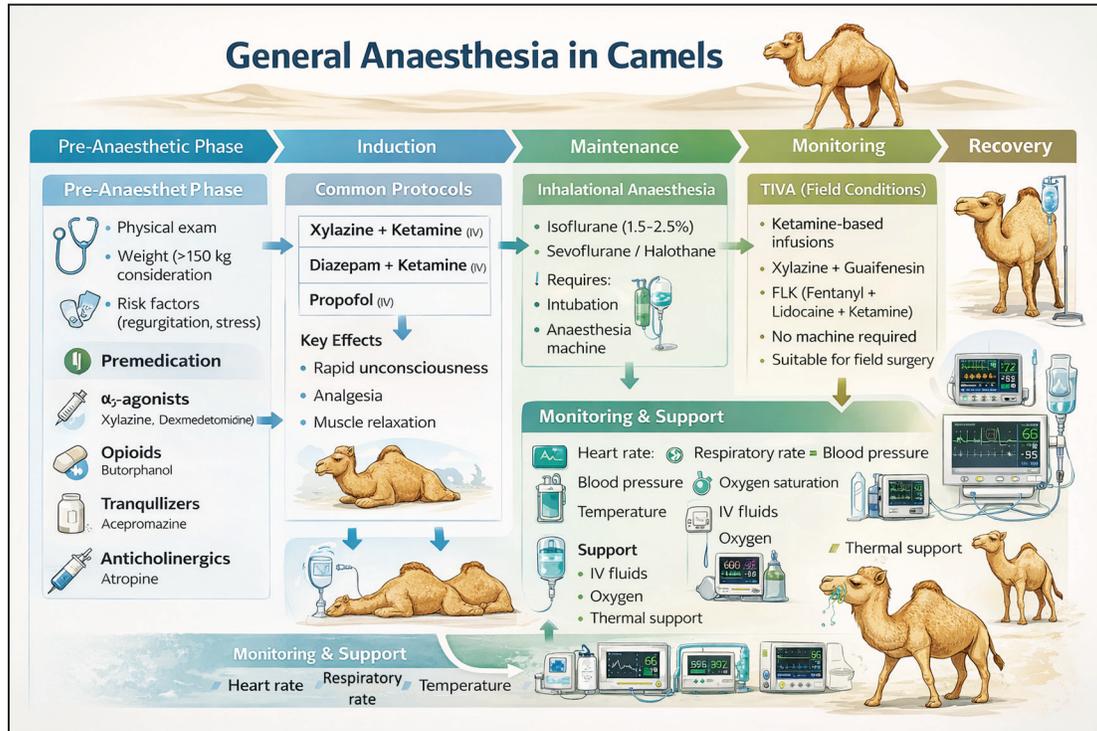


Fig 1. Schematic plan of general anaesthesia in camels with different types, phases and protocols.

camels out of which xylazine and propionyl promazine produced significant hyperglycaemia but did not alter plasma concentrations of urea or aspartate aminotransferase.

Anticholinergic drugs such as atropine or glycopyrrolate may be administered as part of the premedication protocol to reduce salivary secretions and prevent vagally mediated bradycardia during anaesthesia. Atropine is typically administered at doses of 0.02 mg/kg intravenously or 0.04 mg/kg intramuscularly when indicated (Muir *et al*, 2020).

Combination protocols such as xylazine-butorphanol or dexmedetomidine-ketamine are commonly used to achieve balanced premedication in camelids (Nath *et al*, 2023; Nath *et al*, 2024). These combinations provide improved sedation, analgesia, and muscle relaxation, resulting in smoother induction and more stable anaesthesia compared with single-drug protocols.

Maintenance of Anaesthesia in Camels

Maintenance of anaesthesia is the phase during which an adequate depth of anaesthesia is sustained throughout a surgical or diagnostic procedure. In camels, maintenance of anaesthesia may be achieved using inhalational anaesthetic agents or TIVA techniques. The choice of method depends on factors such as availability of equipment, duration

of surgery, field conditions, and the health status of the animal. Balanced anaesthesia using combinations of sedatives, analgesics, and anaesthetic agents is generally preferred because it improves anaesthetic stability and minimises adverse effects.

Inhalational anaesthesia is widely used in veterinary practice for maintaining general anaesthesia during surgical procedures in both Old World camelids (dromedary and Bactrian camels) and New World camelids (llamas and alpacas). This technique provides better control of anaesthetic depth, improved oxygenation, and smoother recovery compared with many injectable anaesthetic protocols. Inhalational anaesthesia is particularly useful for prolonged surgical procedures where continuous adjustment of anaesthetic depth is required.

Principles of Inhalational Anaesthesia

Inhalational anaesthesia involves the administration of volatile anaesthetic agents through the respiratory system using an anaesthetic machine and vaporizer. After induction with injectable anaesthetic agents and successful endotracheal intubation, anaesthesia is maintained by inhalation of volatile anaesthetics mixed with oxygen. The concentration of anaesthetic agent delivered to the patient can be precisely controlled, allowing the anaesthetist to rapidly adjust anaesthetic depth during surgery.

In camelids, inhalational anaesthesia requires careful airway management due to anatomical characteristics such as a relatively narrow oral cavity, elongated soft palate, and tendency for laryngeal reflexes. Proper endotracheal intubation is essential to maintain airway patency and prevent aspiration of gastric contents during anaesthesia (Fowler, 2010).

Inhalational Anaesthetic Agents Used in Camelids

Inhalational anaesthesia remains an important technique for maintaining general anaesthesia in camels and other camelids. Agents such as isoflurane and sevoflurane provide safe and effective anaesthesia with improved control of anaesthetic depth and smooth recovery. However, careful airway management, monitoring of physiological parameters, and appropriate supportive care are essential to minimise complications during inhalational anaesthesia in camelids.

Inhalational anaesthesia is commonly used for maintaining anaesthesia in camels undergoing prolonged surgical procedures. After induction with injectable anaesthetic agents and successful endotracheal intubation, anaesthesia may be maintained using volatile anaesthetic agents delivered through a large-animal anaesthesia machine (Alsobayil *et al*, 2016).

The most commonly used inhalational anaesthetics in camels include isoflurane, sevoflurane, and halothane. Among these agents, isoflurane is widely preferred due to its rapid onset and recovery characteristics, minimal metabolism, and relatively stable cardiovascular effects. Isoflurane allows easy control of anaesthetic depth and provides smooth recovery following prolonged surgical procedures (Grimm *et al*, 2015).

Studies have demonstrated that maintenance of anaesthesia with isoflurane following xylazine-ketamine induction provides satisfactory anaesthesia with stable physiological parameters in dromedary camels. Isoflurane concentrations typically range between 1.5–2.5% depending on the depth of anaesthesia required (Alsobayil *et al*, 2016).

Sevoflurane has also been investigated as an alternative inhalational anaesthetic because of its rapid induction and recovery properties. However, its use in camelids is less common due to higher cost and limited availability in large-animal veterinary practice.

During inhalational anaesthesia, continuous monitoring of cardiovascular and respiratory

parameters is essential. Camels may develop hypoventilation, hypotension, and hypothermia during prolonged anaesthesia. Therefore, supportive measures such as oxygen supplementation, intravenous fluid therapy, and thermal support are recommended (Grimm *et al*, 2015).

Advantages of Inhalational Anaesthesia

Inhalational anaesthesia offers several advantages in camelids, i.e. precise control of anaesthetic depth, rapid adjustment of anaesthetic concentration, smooth recovery following prolonged procedures, improved oxygen delivery and ventilation support and reduced cumulative drug effects compared with injectable anaesthesia. These advantages make inhalational anaesthesia particularly suitable for major surgical procedures such as abdominal surgery, orthopedic interventions, and complex diagnostic procedures.

Physiological Effects and Monitoring

During inhalational anaesthesia, camelids may experience dose-dependent cardiovascular and respiratory depression. Common physiological effects include reduced respiratory rate, decreased blood pressure, and potential hypoventilation. Therefore, continuous monitoring of vital parameters such as heart rate, respiratory rate, arterial oxygen saturation, blood pressure, and body temperature is essential (Grimm *et al*, 2015). Camelids are also susceptible to hypothermia and regurgitation during prolonged anaesthesia. Appropriate supportive care including thermal support, intravenous fluids, and proper positioning in sternal recumbency can help reduce these risks.

Clinical Applications

Inhalational anaesthesia is most commonly used in hospital settings where appropriate anaesthetic equipment is available. It is particularly useful for procedures requiring prolonged anaesthesia, including exploratory laparotomy, orthopedic surgery, and advanced diagnostic procedures. In camelids weighing more than 150 kg, specialised large-animal anaesthesia machines and breathing circuits are often required to maintain adequate ventilation.

Intravenous Anaesthesia in Camels

Intravenous anaesthesia is widely used in camels for both field and hospital surgical procedures because it allows rapid induction, adequate analgesia, and reliable muscle relaxation without the need for sophisticated anaesthetic equipment. In many

regions where camel surgery is performed under field conditions, TIVA represents a practical and effective alternative to inhalational anaesthesia. Intravenous anaesthetic protocols are commonly used for short to moderate duration procedures such as castration, wound management, orthopedic interventions, and exploratory surgery.

Several injectable anaesthetic agents and drug combinations have been described for intravenous anaesthesia in camels. Among these agents, ketamine is one of the most commonly used drugs because of its rapid onset, profound analgesic properties, and relatively wide safety margin. Ketamine produces dissociative anaesthesia characterised by analgesia and unconsciousness; however, when used alone it may cause muscle rigidity and inadequate muscle relaxation. Combinations of α_2 -adrenergic agonists and dissociative anaesthetics such as xylazine-ketamine are widely used for induction of anaesthesia in camels, providing good analgesia and muscle relaxation, while benzodiazepines such as diazepam are sometimes added to improve anaesthetic stability and recovery (White *et al*, 1987; Alsobayil *et al*, 2016; Bani-Ismail, 2016).

The combination of xylazine and ketamine is widely used for induction and short-term intravenous anaesthesia in camels. Xylazine provides sedation,

muscle relaxation, and analgesia, while ketamine induces anaesthesia and maintains analgesia during surgical procedures. This combination has been reported to produce satisfactory anaesthesia with acceptable cardiovascular and respiratory parameters in dromedary camels (Fowler, 2010).

Another intravenous anaesthesia technique involves the use of guaifenesin in combination with ketamine and xylazine. Guaifenesin acts as a centrally acting muscle relaxant and enhances the anaesthetic effects of ketamine, allowing smooth induction and maintenance of anaesthesia. This protocol is often used in large animal anaesthesia to maintain balanced anaesthesia for procedures of moderate duration (Muir *et al*, 2020).

More recently, propofol has been investigated for intravenous anaesthesia in camels because of its rapid onset of action and short recovery time. Propofol provides smooth induction and recovery due to its rapid redistribution and metabolism. It may be administered as intermittent bolus injections or as continuous intravenous infusion for maintenance of anaesthesia. However, careful monitoring is required because propofol may cause respiratory depression and hypotension in some animals.

The use of α_2 -adrenergic agonists such as dexmedetomidine and medetomidine as part of

Table 1. Injectable Anaesthetic Protocols Used in Camels.

Protocol / Drug Combination	Dose (mg/kg)	Route	Purpose	Remarks / Clinical Use
Xylazine	0.1-0.4	IV / IM	Sedation / Premedication	Produces sedation, analgesia and muscle relaxation; commonly used before induction
Ketamine	2-5	IV	Induction	Provides dissociative anaesthesia and analgesia; often combined with sedatives
Xylazine + Ketamine	Xylazine 0.2-0.4 + Ketamine 2-3	IV	Induction and short surgical anaesthesia	Widely used protocol producing reliable anaesthesia in camels
Xylazine + Ketamine + Guaifenesin	Xylazine 0.1-0.2 + Ketamine 1-2 + Guaifenesin 50-100	IV infusion	Total Intravenous Anaesthesia (TIVA)	Provides muscle relaxation and balanced anaesthesia for moderate procedures
Diazepam + Ketamine	Diazepam 0.1-0.2 + Ketamine 2-4	IV	Induction	Improves muscle relaxation and prevents ketamine-induced rigidity
Propofol	2-4	IV	Induction / TIVA	Rapid onset and smooth recovery; may cause respiratory depression
Dexmedetomidine + Ketamine	Dexmedetomidine 2-5 μ g/kg + Ketamine 2-3	IV / IM	Sedation and induction	Provides profound sedation and analgesia
Romifidine + Ketamine	Romifidine 0.04-0.1 + Ketamine 2-3	IV	Induction	Produces prolonged sedation with minimal ataxia
Medetomidine + Ketamine	Medetomidine 5-10 μ g/kg + Ketamine 2-3	IV / IM	Induction	Balanced anaesthesia with good analgesia
Butorphanol + Xylazine	Butorphanol 0.02-0.05 + Xylazine 0.1-0.2	IV / IM	Premedication	Provides synergistic sedation and analgesia

intravenous anaesthetic protocols has also been studied in camelids. These agents produce potent sedation, analgesia, and muscle relaxation, and when combined with ketamine or propofol they contribute to balanced anaesthesia with improved analgesic effects and reduced anaesthetic requirements (Bani-Ismael, 2016).

During intravenous anaesthesia, continuous monitoring of physiological parameters including heart rate, respiratory rate, mucous membrane colour, capillary refill time, and body temperature is essential to ensure anaesthetic safety. Supplemental oxygen and intravenous fluid therapy may be required in prolonged procedures to maintain adequate tissue perfusion and oxygenation.

Overall, intravenous anaesthesia remains a practical and effective technique for camel surgery, particularly under field conditions where inhalational anaesthetic equipment may not be available. Appropriate drug selection, dosage, and monitoring are essential to minimise complications and ensure safe anaesthetic management in camels. Injectable anaesthetic protocol used in camels is given in Table 1.

Maintenance with Total Intravenous Anaesthesia (TIVA)

TIVA is commonly used in field conditions where inhalational anaesthesia equipment may not be available. In this technique, anaesthesia is maintained using continuous or intermittent intravenous administration of anaesthetic agents.

TIVA was used in llama (*Lama glama*) undergoing unilateral ovariectomy. It was found that pre-anaesthetic - xylazine i/v induction by ketamine and maintenance by fentanyl and ketamine (FLK) (fentanyl + lidocaine + ketamine) by continuous infusion demonstrated better physiological and hemodynamic stability with an acceptable level of surgical anaesthesia (Goicochea-Vargas *et al*, 2024).

Various drug combinations have been used for TIVA in camels, including ketamine, xylazine, guaifenesin, propofol, and benzodiazepines. One commonly described protocol involves the combination of xylazine, ketamine, and guaifenesin, which provides good muscle relaxation and stable anaesthesia for short to moderate surgical procedures (Muir *et al*, 2020).

Ketamine-based infusion protocols are widely used because ketamine produces dissociative anaesthesia and provides effective analgesia. However, when used alone, ketamine may cause muscle rigidity

and poor recovery; therefore, it is usually combined with sedatives such as xylazine or diazepam.

Propofol has also been evaluated for maintenance of anaesthesia in camels due to its rapid metabolism and smooth recovery characteristics. Continuous infusion of propofol may provide stable anaesthesia with minimal cumulative effects.

Recent studies have also evaluated the use of α_2 -adrenergic agonists such as romifidine and dexmedetomidine as part of TIVA protocols to improve analgesia and anaesthetic stability in camels. These combinations provide balanced anaesthesia with reduced doses of induction agents and improved recovery quality (Bani-Ismael, 2016).

Although TIVA is practical for field surgeries, careful monitoring is required to prevent respiratory depression and cardiovascular compromise during prolonged procedures.

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Data Availability

The data generated during the study can be requested from the corresponding author.

Conflict of Interest

The authors declare no conflict of interest.

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