수의학석사 학위논문

한국마사회에서 실시한 말의 전신마취에 대한 후향 분석

Retrospective Analysis of Equine General Anesthesia Performed at Korea Racing Authority

2014년 8월

서울대학교 대학원

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이 논문을 수의학 석사 학위논문으로 제출함

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Retrospective Analysis of Equine General Anesthesia Performed at Korea Racing Authority

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Abstract

This study was conducted to analyze the various aspects of inhalation anesthesia performed at the equine hospital of Korea Racing Authority (KRA) to find out the contributing factors to the mortality during and/or after the anesthesia.

A total of 585 horses that were anesthetized at the equine hospital of KRA in Gwacheon and Pusan from 2001 to 2013 were reviewed. Data from anesthetic recorded

included date of anesthesia, breed, age, sex, body weight, anesthetic duration, type of surgical procedure, inhalation agent concentration (vaporizer setting, inspiratory gas, and expiratory gas), heart rate(HR), systolic blood pressure(SBP), mean blood pressure(MBP), diastolic blood pressure(DBP), respiratory rate(RR) and post-anesthetic complications. Unusual events that occurred during or after anesthesia were noted in the comments column on the anesthetic record.

Among 585 cases of anesthesia, orthopedic surgery (410) was performed the most frequently, followed by colic surgery (85) and upper airway surgery (45). Twenty out of 585 horses were either euthanized or died during and/or after anesthesia. Among those twenty horses, fourteen horses received colic surgery, three received orthopedic surgery, and three received upper airway surgery. The major causes of mortality were rupturing of intestine during colic surgery and airway obstruction during recovery in upper airway surgery. Myopathy, refracture, and laminitis were the causes of mortality in orthopedic surgery. The horses that received colic and upper airway surgeries showed statistically significant higher mortality rate than horses that received orthopedic surgery ($p < 0.05$).

The highest mortality rate due to poor and grave prognosis was observed in the horses that received colic surgery. To reduce the perioperative mortality of horses, it is recommended to provide intensive perioperative care for colic surgery and to conduct close monitoring for upper airway surgery during recovery.

Key words: general, inhalation, anesthesia, mortality, horse

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CONTENTS

INTRODUCTION

General inhalation anesthesia has been routinely performed in equine practice and is considered as a fundamental step to treat horses with alimentary, upper airway and orthopedic diseases. The incidence of mortality and serious morbidity associated with clinical equine anesthesia are considerably higher than in other domestic species (2, 10).

Several studies have been published over the years describing the perioperative mortality rates in equine patients. In the study of confidential enquiry of perioperative equine fatalities (CEPEF), the overall mortality rate within 7 days of anesthesia for non-colic cases was 0.8%, while colic cases were nearly 8% (9). In another study, the mortality rate in 35,927 non-colic operations was 0.9%, and in 5,833 colic operations, 7.9% (8).

Anesthesia-related mortality in horses lies between 0.12% and 0.9% (1). The mortality rate for horses undergoing emergency procedures has been shown to be as high as 31.4% for all emergencies (5, 11). A retrospective analysis of anesthesia-associated mortality reported an overall death rate as 1.6% (15). Thirty- two percent of horses among those deaths had to be humanely euthanized because of myopathies or fractures found during recovery (15). Although the mortality rate after anesthesia could be different depending on diseases and preoperative condition of horses, it is necessary to evaluate anesthetic results to reduce the mortality rate of patients during perioperative period.

Although a large number of surgeries requiring general anesthesia have been performed over the last 20 years at the equine hospital of KRA, no comprehensive evaluation of general anesthesia records or retrospective studies of perioperative equine fatalities was performed. The objectives of the study were to analyze the results of inhalation anesthesia performed at the equine hospital of KRA, and to identify the risk factors associated with mortality during and/or after inhalation anesthesia.

MATERIALS AND METHODS

1. Data collection

A total of 585 horses that were anesthetized at the equine hospital of KRA in Gwacheon and Pusan from 2001 to 2013 were reviewed. The horses were either KRA racing horses or horses that required surgery under general anesthesia referred from outside of KRA. Anesthetic records that missed more than five items were excluded from the study. As some records were excluded in each item, total numbers of analyzed records were different from the total number of the general inhalation anesthesia records.

Data from anesthetic records included date of anesthesia, breed, age, sex, body weight, anesthetic duration, type of surgical procedure, inhalation agent concentration (vaporizer setting, inspiratory, and expiratory gas), heart rate (HR), systolic blood pressure (SBP), mean blood pressure (MBP), diastolic blood pressure (DBP), respiratory rate (RR) and post-anesthetic complications. Unusual events that occurred during or after anesthesia were noted in the comments column on the anesthetic record.

2. Anesthetic procedures

Horses were fasted overnight prior to anesthesia except for those that received emergency surgery. About 2 hours before induction, blood samples were collected for hematological and biochemical analyses. Immediately before induction of anesthesia,

horses were sedated with detomidine (Domosedan®; Pfizer, USA, 20~40 μg/kg, IV). Ketamine with either diazepam (Diazepam HCl®; Samjin, Korea, 0.02~0.11 mg/kg, IV) or guaifenesin (Giafen®; Bayer, Germany, 50~100 mg/kg, IV) were used for induction of anesthesia. Once horses became laterally recumbent, oro-tracheal intubation was performed. All horses were controlled by a circle rebreathing anesthetic system at 100% oxygen with intermittent positive pressure ventilation. Anesthesia was maintained with isoflurane (Ifrane®; Hana, Korea) and a ventilation circuit. An indwelling catheter was installed at the facial and/or metatarsal artery, depending on the position and surgery type, which was connected to a calibrated pressure transducer (Transpac IV monitoring kit®; Hospira, Ireland) to monitor direct blood pressure (BP). If MBP was lower than 60 mmHg during anesthesia, dobutamine HCl (Dobutrex®; Hana, Korea) was administered to maintain MBP above 60 mmHg. During anesthesia, horse were monitored every 10 minutes with an anesthetic multi-parameter monitor (Solar 8000®; JD Medical, USA).

After surgery, horses were moved to a recovery room to be ventilated until they were able to initiate spontaneous breathing. The recovery dose of xylazine (Rompun®; Bayer, USA, 1.1 mg/kg, IV) was usually administered for smooth recovery. Nasal insufflation of pure oxygen at 10 L/minutes was given until they started to stand up by themselves. Horses were allowed to recover without assistance in a padded recovery stall.

3. Statistical analyses

Analysis was conducted by statistical software (Stata®; Version 12, Stata Corp LP,

College Station, USA). The mean ± SD was calculated from numerical data. Logistic regression analysis and chi square test were used to assess the relationship between perioperative factors and mortality. Statistical significance was attributed when p value was less than 0.05.

RESULTS

The mean age of the 585 horses was 4 ± 3.1 years (range 1-22 years). Among 558 horses, 223 (40.0%) were females, 236 (42.3%) were sexually intact males, and 99 (17.7%) were castrated males. Among 585 cases, 474 (81%) cases were thoroughbred (TB), 99 (17%) cases were non-thoroughbred (NTB) and 12 (2%) cases were foals (F). There was no significant correlation between breed and mortality (Table 1).

Table 1. Mortality according to groups of horses

Groups	No. of Horses (%)		Total	*p* value
	Alive	Dead		
TB	472 (97.1)	14 (2.9)	486 (100)	
NTB	93 (93.9)	6 (6.1)	99 (100)	0.243
Total	565 (96.6)	20 (3.4)	585 (100)	

NTB: non-thoroughbred, TB: thoroughbred

Among 577 cases, the mean body weight of horses was 472.6 ± 50.4 kg (range 141-675 kg). The weight of 440 (76.2%) horses was less than 500 kg, and the weight of 137 (23.7%) horses was over 500 kg. There was a significant correlation between weight and mortality (Table 2).

Table 2. Mortality according to weight of horses

Weight	No. of Horses (%)		Total	*p* value
	Alive	Dead		
≥ 500 kg	429 (97.5%)	11 (2.5%)	440 (100%)	
< 500 kg	128 (93.4%)	9 (6.6%)	137 (100%)	0.023*
Total	557 (96.5%)	20 (3.5%)	577 (100%)	

*$p < 0.05$

Among 464 horses, 405 (88.5%) were positioned in dorsal recumbency (DR) during anesthesia, 43 (10.6%) were in right lateral recumbency (RLR), and 20 (4.9%) were in left lateral recumbency (LLR). There was no significant correlation between patient position and mortality.

Among 585 cases of anesthesia, orthopedic surgery (410) was the most frequently performed surgery and followed by colic surgery (85), castration (71), and upper airway surgery (45). Mortality rates among horses that underwent colic and upper airway surgery were significantly higher compared to the horses that underwent other types of surgery (Table 3).

Table 3. Mortality according to surgical procedures of horses

Surgery type	No. of Horses (%)		Total	Frequency	*p* value
	Alive	Dead			
Castration	11 (91.7)	1 (8.3)	12 (100)	12 (12.1)	
Colic	72 (84.7)	13 (15.3)	85 (100)	85 (14.5)	
Ortho (I)	70 (98.6)	1 (1.4)	71 (100)	71 (12.1)	
Ortho (NI)	337 (99.4)	2 (0.6)	339 (100)	339 (57.9)	
Soft tissue	17 (100)	0 (0.0)	17 (100)	17 (2.9)	0.000*
Upper Airway	42 (93.3)	3 (6.7)	45 (100)	45 (7.7)	
Others	16 (100)	0 (0.0)	16 (100)	16 (2.7)	
Total	565 (96.6)	20 (3.4)	585 (100)	585 (100)	

Ortho (I): invasive orthopedic surgery, Ortho (NI): non-invasive orthopedic surgery,

*$p < 0.05$

The mean duration from starting inhalation anesthesia to surgical incision was 25.7 ± 9.8 min (n = 584, range 10-80 min). The mean anesthetic duration was 128.1 ± 49.1 min (n = 584, range 20-300 min). The mean recovery period was 48.9 ± 24.9 min (n = 35, range 15-120 min) since the surgery was ended.

The mean ± SD of HR for horses during anesthesia was 36.1 ± 7.3 beat/min (n = 554). The mean ± SD of HR for horses at 30 minutes after starting inhalation anesthesia was 34.4 ± 7.9 beat/min (n = 439). It was gradually increased with prolonged surgery time

The mean SBP, MBP and DBP were 98.6 ± 18.2 mmHg (n = 553, range 46-151 mmHg), 71.7 ± 17.7 mmHg (n = 554, range 32-138 mmHg), and 58.0 ± 18.0 mmHg (n = 552, range 20-110 mmHg) during anesthesia, respectively. The BP was maintained within normal ranges through the surgery. The SBP, MBP, DBP decreased when the total anesthesia time exceeded 230 minutes because of the longer duration of anesthesia in a few patients. The SBP, MBP, DBP were 83.9 ± 13.1 mmHg (n = 12, range 60-114 mmHg), 58.1 ± 13.2 mmHg (n = 11, range 33-78 mmHg), and 44.5 ± 14.8 mmHg (n = 11, range 17-68 mmHg) at 240 minutes after starting inhalation anesthesia, respectively.

The concentration of anesthetic agent was recorded by vaporizer setting percentage. Anesthetic agent concentration decreased when the level of anesthesia reached the surgical phase, which was evaluated by assessing palpebral reflex and corneal reflex. The mean vaporizer setting was 3.5 ± 0.6 % (n = 583, range 2-5 %). The vaporizer setting at 30 minutes after starting inhalation anesthesia was 4.0 ± 1.0 % (n = 583, range 2-5 %). The mean inspiratory and expiratory anesthetic gas concentrations were

2.1 ± 0.4 % (n = 34, range 1.3-3.0 %) and 1.6 ± 0.3 % (n = 34, range 1.0-2.2 %) during maintenance of anesthesia, respectively.

Among 585 of the anesthetic cases, 20 horses were euthanized or died during and/or after anesthesia. Among these 20 horses, 14 received colic surgery, 3 received orthopedic surgery, and 3 received upper airway surgery. Horses that received colic surgery and airway surgery showed significantly higher mortality rates compared to horses that received musculoskeletal system surgery (Table 4).

Table 4. Logistic regression to find out influencing factors on mortality during and/or after anesthesia (n = 508)

Variables	Coefficient	SE	OR	Z	P>|z|
Anesthetic duration	-0.006	0.006	0.994	-1.08	0.278
Anesthetic agent concentration	0.795	0.653	2.215	1.22	0.224
Mean MBP	-0.032	0.034	0.968	-0.97	0.334
Mean HR	0.043	0.035	1.044	1.24	0.215
Colic surgery	3.658	0.762	38.802	4.8	0.000*
Upper airway surgery	2.781	0.884	16.136	3.15	0.002*

HR: heart rate, MBP: mean blood pressure, OR: odds ratio, SE: standard error, $^{*}p < 0.05$

Among the 20 horses, 16 horses were euthanized and 4 horses died during and/or after anesthesia. All horses that were euthanized (13) during general anesthesia were considered to have a poor to grave prognosis for survival. Causes for euthanasia of horses during and/or after recovery were laminitis (1), myopathy (1), and refracture (1). Among the 4 horses that died, 3 horses developed upper airway obstruction while in recovery, and 1 horse had recurrent signs of abdominal pain before dying (Table 5).

In colic cases, significant risk factors such as elevated HR, RR, abnormal mucus membrane color and gastric reflux were recorded under pre-anesthetic comments. The causes of death included endotoxemia, due to intestine rupture prior to surgery, and severe volvulus and torsion that were unable to be corrected surgically. Perioperative fatalities were high at 16.4 % in colic surgery, followed by 0.7 % in orthopedic surgery, and 6.6 % in airway surgery.

Table 5. Detail information of horses died or euthanized during and/or after general anesthesia

	B	A	S	W	Operation	Cause of death	T	O	Comments
1	TB	3	F	456	Colic	Intestine rupture	DA	E	MM: pale pink
2	TB	6	M	450	Colic	Intestine rupture	DA	E	MM: pale pink, HR: 72/min, RR: 64/min
3	TB	3	G	426	Colic	Intestine rupture	DA	E	
4	TB	5	F	465	Colic	Intestine rupture	DA	E	
5	NTB		M	606	Colic	Intestine rupture	DA	E	HR: 120/min, irregular respiration
6	NTB	11	M	565	Colic	Intestine rupture	DA	E	Eye reflex remained
7	NTB	9	M	581	Colic	Small intestine strangulation	DA	E	MM: blue, CRT 3~4 sec
8	TB	2	M	510	Colic	Intestine rupture	DA	E	MM: dark red, hypotension gastric reflux thorough nasal cavity
9	NTB	11	G	570	Colic	Cecum, large colon displacement	DA	E	MM: pale pink, hypotension
10	NTB	13	F	538	Colic	Ileocecal intussusception	DA	E	
11	TB	4	M	525	Cpx chip fx	Laminitis of BF	AR	E	
12	TB	3	M	454	Colic	Intestine rupture	DA	E	tachycardia

13	Foal	2	M	260	Colic	Inoperable problem	DA	E	$EtCO_2$: 70 mmHg
14	NTB	9	G	540	DDSP	Airway obstruction	DR	N	
15	TB	3	F	515	RC3 slab fx	Myopathy	AR	E	
16	TB	4	F	473	DDSP	Airway obstruction	DR	N	
17	TB	4	F	467	LMT3 Fx	Refracture	DR	E	
18	TB	2	F	450	Colic	Inoperable problem	DA	E	
19	TB	3	G	491	LH	Airway obstruction	DR	N	
20	TB	2	F	440	Colic	Colic recurrence	AR	N	

A: age, AR: after recovery, B: breed, BF: both forelimbs, BUN: blood urea nitrogen, cpx: carpal bone, CRT: capillary refill time, DA: during anesthesia, DDSP: dorsal displacement of the soft palate, DR: during recovery, E: euthanasia, F: female, fx: fracture, G: gelding, HR: heart rate, LH: laryngeal hemiplegia, LMT3: left third metatarsal bone, M: male, MM: mucus membrane, N: natural death, NTB: non-thoroughbred, O: outcome, RC3: radial carpal bone, RR: respiratory rate, S: sex, T: time of death, TB: thoroughbred, W: weight

DISCUSSION

Epidemiological studies of anesthetic and surgical mortality are effective methods of studying incidents in anesthesia during surgery, and modification needed in anesthetic and surgical practice to reduce perioperative complications (6, 8, 9). Confidential enquiry of perioperative equine fatalities (CEPEF) has already provided much information suggesting how clinical practice could be changed to improve the anesthetic and surgical managements of equine patients (6).

Several studies about perioperative fatality were conducted recently. In most studies, mortality rates were calculated separately in cases of colic and non-colic surgery because the low survival rate in colic surgery might have occurred by their primary disease (1, 5, 8). In the current study, the fatality rate in colic cases was higher (16.4%, n = 14/85) compared to non-colic cases (1.2%, n = 6/500). Logistic regression used to find out influencing factors on fatality showed a significant estimated odds ratio (OR) for colic surgery (CI: 3.658, OR: 38.82) and respiratory surgery (CI: 2.781, OR: 16.136).

The result of colic surgery could be caused by death and/or euthanasia including endotoxemia due to intestine rupture before surgery, severe volvulus and torsion that could not be corrected surgically. Although colic horses that developed hypotension or PaO_2< 10.6 kPa during anesthesia had an increased fatality rate in the previous study (14), there was no significant effect of blood pressure on perioperative fatality in the present study.

In case of upper airway surgery, airway obstruction was the main cause of death during and after recovery. Nasal cavity edema was the most common cause of post-operative respiratory obstruction (4). Three horses died due to airway obstruction in the recovery room after airway surgery including tie-forward or tie-back techniques. Therefore, maintaining a patient's airway and supplying sufficient oxygen levels are crucial steps during recovery from anesthesia. Keeping the oro-tracheal tube in the airway until full recovery is also recommended. In addition, it was reported that the incidence of postoperative complication was greater in draft horses than thoroughbreds in laryngoplasty cases (12), but this comparison could not be carried out in the current study due to insufficient number of airway surgery in draft horses.

Complications such as fractures accounted for 23-26 % of the mortality rate associated with inhalant anesthesia, and myopathy or neurological complications represent 7 % of mortality causes (7, 8). In this study, one out of 20 horses showed refracture as a post-operative complication. It is worth noting that post-operative fractures represented nearly 1/4 of all deaths and that these fractures were not restricted to horses undergoing fracture repair (8). Therefore, surgeons always need to be aware of the possibility of post-operative fracture in the recovery room regardless of the types of surgery.

Although the MBP was maintained within normal ranges above 60 mmHg during anesthesia, one horse experienced myopathy in the recovery room after orthopedic surgery in this study. Myopathy can be a serious or fatal complication of equine anesthesia. Its incidence and severity can be reduced by maintaining muscle perfusion through a combination of careful positioning which reduces the intra-compartmental

pressure and allows free venous drainage, by avoiding prolonged hypotension (17). Hypotension and duration of anesthesia play an important role in the development of postoperative myopathy and neuropathy in draft horses with acute abdominal disease (13). Dobutamine, a synthetic positive inotrope, has been widely used to treat the anesthetic-induced hypotension in conjunction with intravenous fluid therapy and minimizing the delivered concentration of volatile agent (3). Therefore, proper use of ionotropes with fluid to maintain blood pressure and to prevent myopathy is also recommended.

To minimize recovery complications from anesthesia, 1) proper positioning and providing adequate padding of the patient intra-operatively, 2) maintaining MBP above 70 mmHg during anesthesia, 3) providing adequate analgesia for safe recovery, 4) ensuring patency of airway after extubation, and 5) insufflating O_2 at a flow rate of 15 L/ min are generally recommended in routine clinics (4). Improved recovery from anesthesia is associated with shorter, less invasive surgical procedures and slower recovery (18). Consequently, anesthetic management of horses undergoing surgery can be improved greatly, particularly when BP is monitored, hypotension is treated, post-anesthetic myopathy is prevented and ventilation is controlled (16).

In conclusion, careful analysis of anesthetic and surgical results and assessment of the influencing factors on mortality would help reduce fatalities in equine clinics. It is recommended to prepare and perform perioperative intensive care for colic surgery and close monitoring for upper airway surgery during recovery. For further progress, it is also important to complete the anesthetic record for all patients that receive general anesthesia and surgery.

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국 문 초 록

한국마사회에서 실시한 말의 전신마취에 대한 후향 분석

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김 아 람

본 연구는 한국마사회 동물병원에서 시행한 전신마취 결과를 분석하고 마취 중·후에 발생한 사망률에 영향을 미치는 인자를 찾기 위하여 실시되었다. 총585두의 환마에서 전신마취가 실시되었으며, 수술의 빈도는 정형외과 수술(410)이 가장 많이 실시되었고, 산통 수술(85), 호흡기 수술(45) 순이었다. 585두 중 20두가 마취 중·후에 죽거나 안락사 되었다. 20두 중 14두는 산통 수술을 받았고, 3두는 정형외과 수술, 3두는 호흡기 수술을 받았다. 세부 사망원인으로는 산통 수술에서는 장파열, 호흡기 수술에서는 기도폐색이었다. 정형외과 수술에서는 근육병증, 재골절, 제엽염이 안락사의 원인이었다. 결과적으로 산통 수술과 호흡기 수술 후의

사망률은 정형외과 수술 후보다 높게 나타났다($p < 0.01$).

이상의 결과로부터, 산통수술을 받는 말의 사망률이 가장 높은 것을 확인하였으며, 주요 원인은 예후불량에 의한 안락사이었다. 말의 마취 전후 사망률을 낮추기 위하여, 산통 수술을 받는 말은 수술 전후의 집중 관리가 필요하고, 호흡기 수술을 받는 말은 회복 중 주의 깊은 관찰이 추천된다.

주요어: 전신, 흡입, 마취, 사망률, 말

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