Papers

Retrospective study of the prevalence of postanaesthetic hypothermia in dogs

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The anaesthetic records of 1525 dogs were examined to determine the prevalence of postanaesthetic hypothermia, its clinical predictors and consequences. Temperature was recorded throughout the anaesthesia. At the end of the procedure, details coded in were: hyperthermia (>39.50°C), normothermia (38.50°C–39.50°C), slight (38.49°C–36.50°C), moderate (36.49°C–34.00°C) and severe hypothermia (<34.00°C). Statistical analysis consisted of multiple regression to identify the factors that are associated with the temperature at the end of the procedure. Before premedication, the temperature was 38.7±0.6°C (mean±sd). At 60, 120 and 180 minutes from induction, the temperature was 36.7±1.3°C, 36.1±1.4°C and 35.8±1.5°C, respectively. The prevalence of hypothermia was: slight, 51.5 per cent (95 per cent CI 49.0 to 54.0 per cent); moderate, 29.3 per cent (27.1–31.7 per cent) and severe: 2.8% (2.0–3.7%). The variables that associated with a decrease in the temperature recorded at the end of the anaesthesia were: duration of the preanesthetic time, duration of the anaesthesia, physical condition (ASA III and ASA IV dogs showed lower temperatures than ASA I dogs), the reason for anaesthesia (anaesthesia for diagnostic procedures or thoracic surgery reduce the temperature when compared with minor procedures), and the recumbency during the procedure (sternal and dorsal recumbencies showed lower temperatures than lateral recumbency). The temperature before premedication and the body surface (BS) were associated with a higher temperature at the end of the anaesthesia, and would be considered as protective factors.

Introduction

In humans, the exposure to a cool operating room environment and the anaesthetic-induced impairment of thermoregulatory control cause most of the anaesthetised patients to become hypothermic (Sessler 2001). Some 28.3–57.8 per cent of humans are admitted to intensive care units, postsurgery, with a temperature below 35°C (Kongsayreepong and others 2003, Abelha and others 2005), and 97.5 per cent of cats showed a temperature below 36.5°C after anaesthesia (Redondo and others 2012). There are some papers that look at the incidence of hypothermia and interventions in dogs (Evans and others 1973, Waterman 1975, Raffe and Martin 1983, Pottie and others 2007, Oliver and others 2010), but it has been documented in a limited way. Our study is the first that investigates this complication in a large population.

In human medicine, perioperative hypothermia is associated with various adverse outcomes, including an increase in the incidence of surgical wound infection (Kurz and others 1996), higher intraoperative blood loss (Schmied and others 1996), more frequent morbid cardiac events and postoperative ventricular tachycardia (Frank and others 1992), and longer postoperative shivering (Just and others 1993), postanaesthetic recovery (Lenhardt and others 1997) and hospitalisation (Kurz and others 1996). In dogs, hypothermia is a common complication of general anaesthesia and surgery, and is associated with a slower recovery from anaesthesia (Pottie and others 2007).

The aims of this study were to estimate the prevalence of hypothermia in anaesthetised dogs and to retrospectively identify its clinical predictors. A second objective was to evaluate the outcome measured in terms of the length of time to extubation (TEXT) and mortality.

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Materials and methods

Dogs

A retrospective study was performed on the anaesthetic records of dogs anaesthetised at the Veterinary Clinical Hospitals of the Cardenal Herrera University (Valencia, Spain), and the University of Córdoba (Córdoba, Spain). The animals were anaesthetised to carry out various surgical or diagnostic procedures. Only animals with complete records (anaesthetised at the operating theatres, x-ray rooms and CT scan rooms of both hospitals and in which endotracheal intubation was performed), were studied. The anaesthetist chose the anaesthetic protocol, the circuit, the use of mechanical ventilation (or not) and the fluids employed.

The environmental temperature at the hospitals was controlled by air conditioning at between 20°C and 25°C. Dogs were placed on a plastic mat during the procedures (Soporte quirúrgico colchón 50×100 cm, Henry Schein, Spain). Active methods were not used to warm the dogs during the anaesthesia. The only devices used were blankets.

Studied variables

The following data were recorded:

- Signalment: sex (SEX); age in months (AGE); weight of the dog in kg (WEIGHT); BS was calculated as: BS (in m^2)=(10.1×WEIGHT$^{2/3}$)/100 (Rosenthal 1995).
- Reason for the anaesthesia, coded into six groups: minor surgery (MIN, ie, wound suture, removal of single lumps, orchidectomy, dental procedures, etc); orthopaedic and trauma surgery (ORTH, ie, fracture and luxation repair, etc); abdominal surgery (ABD, ie, enterectomy, caesarean section, ovariohysterectomy, etc); diagnostic techniques (DIAG, ie, endoscopy, computerised axial tomography, radiography, etc); thoracic surgery (THOR, ie, patent ductus arteriosus, lung lobectomy, etc) and experimental anaesthesia (EXP, ie, dogs anaesthetised in experimental anaesthetic studies).
- Physical condition of the animal, according to American Society of Anesthesiologists (ASA) criteria. ASA V dogs were excluded from the study.
- The recumbency during the anaesthesia was recorded as dorsal recumbency (DR), lateral recumbency (LR) or sternal recumbency (SR). In animals with multiple recumbencies (eg, dorsal and lateral), the recumbency in which the dog spent the longest period of time was considered.
- Baseline temperature (TAB). The rectal temperature was measured before the procedure using a digital thermometer (Thermoval Classic, Hartmann International, Bensheim, Germany).
- Oesophageal temperature (TA) was recorded every five minutes after induction during the anaesthesia using a miltiparametric monitor (AS3 Haemodynamic and Respiratory Monitor, Datex-Ohmeda, Inc, Madison, Wisconsin, USA).
- Final temperature (TAF) was defined as the temperature recorded at the end of the procedure, when the administration of the hypnotic (intravenous or volatile agent) was stopped. TAF was coded in a new ordinal variable called HYPOTH, into five ranks: hyperthermia (TAF > 39.50°C), normothermia (38.50°C–39.50°C), slight hypothermia (38.49°C–36.50°C), moderate hypothermia (36.49°C–34.00°C) and severe hypothermia (TAF<34.00°C).
- The duration of the procedure was divided in three phases: preanaesthetic time (TPRE: time, in minutes, from the administration of the premedication to anaesthesia induction); anaesthetic time (TANES: time, in minutes, from the induction to the end of the administration of the hypnotic), and time to extubation (TEXT: time in minutes from the end of hypnotic administration to the recovery of voluntary swallowing).
- Anaesthetic death was recorded if dogs died in the period between the administration of premedication and 72 hours after endotracheal extubation. Dogs euthanased during the procedure because they had severe pre-existing lesions, were excluded from this study.

Statistical study

Statistical analysis was performed with Statistica for Windows, V.6.0. (StatSoft, Inc. (2001). Tulsa, Oklahoma, USA).

Coding the variables

Three types of predictor variables were coded in the model: (a) those variables coding values of continuous variables, such as age, weight, BS, duration of the procedure, temperature, and so on; (b) those coding the dichotomous state, that is, sex; the variable was coded as '1' if the animal was female and '0' if it was male; (c) those categorical, such as physical condition, reason for anaesthesia and recumbency, where 'dummy' using k – 1 indicator variables for k categories of the item is set up (Table 1) (Wolters and others 1996). To simplify our model, the reference categories for physical condition, reason for anaesthesia, and recumbency were, respectively, ASA I, MIN and LR.

Statistical analysis

Data were examined for normality using the Kolmogorov-Smirnov test. When normal data distribution was found, parametric statistics were applied. When data were non-normally distributed, non-parametric Fisher's exact test was used. In all analyses, the differences were considered statistically significant if P<0.05. Three different statistical studies were performed.

The first analysis described the studied population, the temperature evolution during the anaesthesia, and the incidence of hypothermia at the end of the procedure. The second described the relationship between hypothermia and sex, age, BS, time from sedation to anaesthesia induction, the duration of the anaesthesia, physical condition, reason for anaesthesia and recumbency, and was estimated using multiple regression. In this analysis, data greater or less than three times the SD were considered outliers, and were excluded from the analysis. Non-significant variables were removed one by one, removing the largest P value first, until all remaining variables in the model were significant.

The third analysis studied the relationship between the degree of hypothermia reached at the end of the procedure, the TEXT and the incidence of death between the administration of premedication and 72 hours after endotracheal extubation. For this, a linear regression between TEXT and the temperature at the end of the procedure (TAF) were performed, as well as an analysis of variance (ANOVA), and a posthoc Tukey's test for comparing TEXT of the five ranks considered in HYPOTH. Finally, a Fisher's exact test was performed to study the incidence of the deaths by ranks of HYPOTH.

TABLE 1: Indicator variables for physical condition American Society of Anesthesiologists (ASA), reason for the anaesthesia, and recumbency

	Indicator variables				
Physical condition	ASA(1)	ASA(2)	ASA(3)		
ASA I	0	0	0		
ASA II	1	0	0		
ASA III	0	1	0		
ASA IV	0	0	1		
Reason	REA(1)	REA(2)	REA(3)	REA(4)	REA(5)
MIN	0	0	0	0	0
ORTH	1	0	0	0	0
ABD	0	1	0	0	0
DIAG	0	0	1	0	0
THOR	0	0	0	1	0
EXP	0	0	0	0	1
Recumbency	REC(1)	REC(2)			
LR	0	0			
DR	0	1			
SR	1	0			

ABD Abdominal surgery, DIAG Diagnostic techniques, DR Dorsal recumbency, EXP Experimental anaesthesia, LR Lateral recumbency, MIN Minor surgery, ORTH Orthopaedic and trauma surgery, THOR Thoracic surgery, SR Sternal recumbency

Results

A total of 1525 anaesthetic records of dogs were included in this study. Other 142 dogs were excluded because they were not anaesthetised at the operating theatres, the x-ray room or the CT scan room, and 71 were also excluded because full records were not available. Eighteen dogs were euthanased during the procedure, and they were also excluded from the study.

Seven hundred and eighty males and 745 females were recorded. The dog's age (mean±sd) was 3.8±3.3 years (range: 2 months–19.3 years) and their weight was 18±11 kg (1–84 kg).

According to ASA criteria, 650 ASA I, 519 ASA II, 262 ASA III and 94 ASA IV dogs were studied. The reason for performing the anaesthesia was coded into six groups: MIN, 375 animals; ORTH, 394; ABD, 224, DIAG, 165, THOR, 22 and EXP, 345. The recumbency during the procedure was: LR, 970; DR, 426 and SR, 129. Median preanesthetic time (TPRE) was 18 minutes (range: 1–138 minutes). Median duration of the anaesthesia (TANES) was 65 minutes (range: 5–440 minutes). One hundred and sixty-four different anaesthetic protocols were used.

Mean TAB was 38.7±0.6°C (range: 32.8°C–40.5°C). Twenty-four thousand, one hundred and thirty-seven (24137) perioperative

TABLE 2: Total incidence of hypothermia in relation to sex, physical condition American Society of Anesthesiologists (ASA), reason for the anaesthesia, and recumbency

	N	Hyperthermia	Normothermia	Slight hypothermia	Moderate hypothermia	Severe hypothermia
Sex						
Male	780	22	109	408	222	19
Female	745	9	111	377	225	23
ASA						
I	650	16	142	331	151	10
II	519	8	53	273	175	10
III	262	5	20	129	93	15
IV	94	2	5	52	28	7
Reason						
MIN	375	12	54	211	95	3
DIAG	165	2	20	105	34	4
ORTH	394	9	37	189	146	13
ABD	224	3	12	107	90	12
THOR	22	0	0	7	9	6
EXP	345	5	97	166	73	4
Recumbency						
LR	970	26	171	487	267	19
DR	426	3	30	220	156	17
SR	129	2	19	78	24	6
Total	1525	31	220	785	447	42

ABD Abdominal surgery, DIAG Diagnostic procedures, DR Dorsal recumbency, EXP Experimental anaesthesia, LR Lateral recumbency, N Number of cases, MIN Minor surgery, ORTH Orthopaedic surgery, THOR Thoracic surgery, SR Sternal recumbency

temperature readings were recorded (mean 36.9±1.5°C; range: 30.1°C–41.2°C). The temperature evolution during the procedure is presented in Fig.1. At 5, 60, 120 and 180 minutes from induction, the temperature was (mean±sd) 37.8±1.1°C (range: 33.4°C–40.5°C), 36.7±1.3°C (31.5°C–40.4°C), 36.1±1.4°C (31.5°C–40.4°C) and 35.8±1.5°C (31.7°C–39.7°C), respectively. At the end of the procedure, 31 dogs were considered to have hyperthermia (2.9 per cent; 95 per cent CI 1.4 to 2.9 per cent); 220 normothermia (14.4 per cent; 95 per cent CI 12.8 to 16.3 per cent); 785 slight hypothermia (51.5 per cent; 95 per cent CI 49.0 to 54.0 per cent); 447 moderate hypothermia (29.3 per cent; 95 per cent CI 27.1 to 31.7 per cent); and 42 severe hypothermia (2.8 per cent; 95 per cent CI 2.0 to 3.7 per cent). The prevalence of hypothermia on sex, ASA, reason for anaesthesia, and recumbency are shown in Table 2.

The multiple regression model showed that there were some clinical predictors of the temperature at the end of the procedure (Table 3). Nineteen cases were excluded in this analysis (31.0, 31.0, 31.3, 32.0, 32.3, 32.5, 33.0, 33.0, 33.3, 33.3, 33.6, 33.9, 37.8, 37.9, 38.1, 38.2, 39.4, 41.2 and 40.2 (all figures in °C)) because they were considered outliers. The variables associated with a decrease in the temperature recorded at the end of the anaesthesia were: preanaesthetic time, duration of the anaesthesia, physical condition (ASA III and IV dogs showed lower temperatures than ASA I dogs), the reason for the anaesthesia (anaesthesia for diagnostic procedures or THOR were associated with statistically significant reduction in the temperature when compared with minor procedures), and the recumbency of the dog during the anaesthesia (animals placed in sternal or DR showed lower temperatures than dogs put in LR). On the other hand, the TAB before the anaesthesia, and the BS, were the variables found to have increased the TAF. Sex and age were not significant predictors.

The simple linear regression between time to extubation (TEXT) and the temperature at the end of the procedure (TAF) did not show a relationship between these variables (R=0.039; P=0.164). However, TEXT of severely hypothermic dogs was statistically longer than the other groups. Data are shown in Table 4.

Twelve dogs died between the administration of premedication and 72 hours after endotracheal extubation (0.79 per cent, 95 per cent CI 0.45 to 1.37 per cent). Four dogs died by pre-existing lesions, two by cardiovascular collapse, and in six cases the cause of death was not established. Five dogs were male and seven female. At the moment of the death, one of the dogs showed normothermia, five mild hypothermia and six moderate hypothermia. There were no differences in the prevalence of death after studying the different groups. Data are shown in Table 4.

Discussion

The normal canine temperature range is 37.8°C –39.2°C (Armstrong and others 2005). Hypothermia is defined as a core body temperature less than 37.0°C (Pottie and others 2007). Three classes are recognised in dogs: mild (32°C–35°C), moderate (32°C–28°C) and severe (<28°C) (Armstrong and others 2005). Using this classification, most

TABLE 3: Predictors of temperature (°C) at the end of the procedure in 1525 dogs by multiple regression analysis

	Unstandarised coefficients	Standardised coefficients			95% confidence interval for B	
	B	se	Beta	P value	Lower bound	Upper bound
(Constant)	20.460	2.373		0	15.810	25.119
Baseline temperature	0.441	0.061	0.152	0	0.320	0.561
Body surface	1.451	0.112	0.274	0	1.232	1.670
Preanaesthetic time	−0.010	0.002	−0.120	0	−0.014	−0.006
Duration of anesthesia	−0.010	0.001	−0.385	0	−0.011	−0.009
ASA	−0.122	0.035	−0.075	0.001	−0.191	−0.052
Thoracic surgery	−1.645	0.252	−0.139	0	−2.138	−1.151
Diagnostic procedures	−0.227	0.098	−0.050	0.021	−0.420	−0.034
Dorsal recumbency	−0.507	0.071	−0.158	0	−0.646	−0.369
Sternal recumbency	−0.262	0.110	−0.052	0.017	−0.477	−0.046

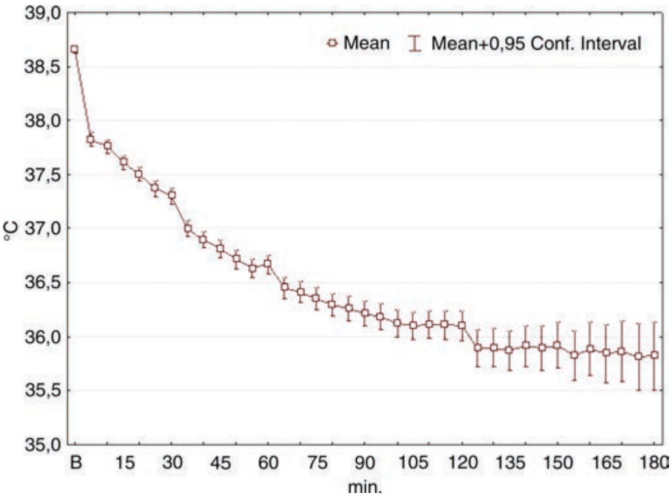

FIG 1: Mean (95 per cent CI) body temperature during the first three hours of anaesthesia in 1525 dogs

TABLE 4: Deaths, mortality index and time to extubation in minutes (mean±sd) by ranks of hypothermia

	N	Deaths	Mortality index (%)	Time to extubation (minutes)
Hyperthermia	31	0	0	10±9
Normothermia	220	1	0.45	8±5
Slight hypothermia	785	5	0.64	8±6
Moderate hypothermia	447	6	1.34	7±6
Severe hypothermia	42	0	0	14±21
Total	1525	12	0.79	8±7

N Total number of cases, Deaths Number of dogs that died

readings would be included in the range of mild hypothermia. As only five dogs (0.33 per cent) fell below 32°C, with none below 28°C, the categories were modified based on our own opinions, to facilitate analysis.

In human medicine, hypothermia is a very frequent and well-known complication of anaesthesia (Kongsayreepong and others 2003,[b1] Abelha and others 2005, Kiekkas and others 2005). To our knowledge, the incidence of postanaesthesia hypothermia in dogs has not been documented in clinical studies. Our study shows a very high incidence of this complication: 83.6 per cent of dogs had hypothermia at the end of the anaesthetic procedure (TAF<36.5°C).

There are a variety of causes associated with perioperative hypothermia. This study identified several factors associated with the evolution of body temperature during the anaesthesia in the dog. They can be summarised in three groups: first, variables related with the animal's signalment (TAB and BS); secondly, variables associated with the physical condition and the intervention (ASA, reason for the anaesthesia and recumbency during the anaesthesia); and thirdly, the duration of the procedure (preanesthetic time and duration of the anaesthesia).

The TAB was a very important factor. In this study, a warmer preoperative body temperature was considered a significant protective factor for hypothermia, as has also been demonstrated in human medicine (Just and others 1993, Kongsayreepong and others 2003, Abelha and others 2005). It has been suggested that efforts should be made to increase body temperature before surgery, which is supported by our findings. Increasing the operating room temperature (Kongsayreepong and others 2003, Abelha and others 2005) and the use of dog-warming devices (Machon and others 1999) may prevent heat loss during anaesthesia.

Lower BS was also found to be a significant protective factor against core hypothermia, as has been observed previously in humans (Kongsayreepong and others 2003). Smaller animals have a relatively large surface area in relation to body weight, so proportionally, more heat is lost through their skin, leaving them more susceptible to perioperative hypothermia than larger animals. Most heat loss is by radiation from the skin surface as a function of the skin-to-environment temperature gradient (Cabell and others 1997). For this, supplementary efforts should be made to prevent hypothermia in smaller dogs.

As in human patients, the higher the ASA physical status, the greater the risk of hypothermia. High-risk animals have problems regulating their temperature, thus increasing their risk for core hypothermia (Kongsayreepong and others 2003). However, some of the association detected may result from the relation between ASA and procedure, because sicker dogs may, on average, have more invasive and/or longer procedures. Again, additional efforts may therefore be necessary to prevent hypothermia during anaesthesia in ASA III and IV dogs.

The reason for the anaesthesia was a significant risk factor for core hypothermia at the end of the procedure. In human medicine, the magnitude of the surgical procedure is a well-known risk factor (Kongsayreepong and others 2003, Abelha and others 2005). The most hypothermia-inducing procedure was THOR. When the chest is open, the thoracic organs are exposed; evaporation from serosal surfaces can account for up to 50 per cent of total heat loss during extensive thoracic or abdominal surgeries (Cabell and others 1997). The anesthesias carried out to perform diagnostic procedures also resulted in more hypothermia at the end of the procedure. This has also been found to occur in human anaesthesiology (Melloni 2005). These anesthesias are frequently administered outside the operating theatre, at the x-ray and CT scan rooms, which are normally kept at a lower room temperature to avoid overheating the equipment, and to improve the comfort of the technicians (Melloni 2005), and often the animal is placed directly on the table to avoid interference and they are not covered with cloths. The temperature of the room in which the anaesthesia is administered has been shown to be one of the factors that influence the onset of postoperative hypothermia in humans (Kongsayreepong and others 2003, Tander and others 2005).

The duration of the anaesthesia was associated with the appearance of hypothermia, as has been reported in human anaesthesiology (Slotman and others 1985, Bush and others 1995, Kongsayreepong and others 2003). In our study, the time between the administration of the premedication until anaesthesia induction, and the duration of the anaesthesia, were two major factors that caused hypothermia. The loss of temperature during premedication is very important, from 38.9±0.6°C before premedication to 37.8±1.1°C five minutes after induction. In this phase, the dog is under the effects of sedatives and analgesics; its basal metabolism and heat production are reduced, and heat loss is increased. In the preparation for surgery, the dog is shaved, the surgical field is disinfected with antiseptic solutions, and fluid therapy begins to be administered in most cases, causing the body temperature to fall (Sessler 2000). After induction, a gradual decrease in the temperature is also observed. General anaesthesia removes a patient's ability to regulate their body temperature through behaviour, so that autonomic defences alone are available to respond to temperature changes. Anaesthetics inhibit thermoregulation in a dose-dependent manner, and inhibit vasoconstriction and shivering (Sessler 1997). This temperature drop is not linear. According to our data, in the first three hours, the dogs lost 2.0°C, 0.6°C, and 0.3°C, respectively. In humans, hypothermia during general anaesthesia has three distinct phases. Initially, the core temperature decreases rapidly by 1°C–1.5°C during the first hour, with a slower, linear decrease occurring over the next two to three hours. The dog then enters a plateau phase during which the core temperature remains relatively constant (Armstrong and others 2005). Consequently, basic preventive measures would be to accelerate the animal's preparation during the preanaesthetic time, and to shorten the procedure if it is possible.

The effect of different anaesthetic protocols on postoperative hypothermia has not been investigated in this study in order to simplify the model. Some drugs are known to cause vasodilation, thus facilitating heat loss, while other drugs cause vasoconstriction. Further studies may clarify this point.

The relationship between hypothermia, TEXT and anaesthetic death were also studied. In severely hypothermic dogs, TEXT was significantly longer than in the other groups. A slower recovery from anaesthesia has been previously observed in hypothermic dogs (Pottie and others 2007). Hypothermia reduces the anaesthetic requirements, as it delays the hepatic metabolism of the drugs, prolongs their action and delays recovery from anaesthesia (Haskins 1993). However, the effect of the preanaesthetic medication and anaesthetic agents used during anaesthesia has not been investigated in our study, in order to simplify the model. Some anaesthetic protocols may result in longer TEXT independently of temperature, and this may affect the results.

Twelve dogs died (0.79 per cent). In nine cases, the cause of death was related to pre-existing lesions or anaesthetic complications not directly related to hypothermia. However, in three dogs that died during the 24 hours following extubation (one normothermic and two moderately hypothermic), the cause was unable to be determined. In human anaesthesiology, hypothermia is associated with significantly increased mortality rates during the postoperative period (Bush and others 1995), so hypothermia may have contributed to exacerbation of the dog's condition and facilitated its death. Nevertheless, our study could not demonstrate a relationship between hypothermia and an increase in mortality during the first 72 hours after anaesthesia. Clinical studies involving a larger number of dogs are required to confirm this finding.

In conclusion, hypothermia is a very frequent complication of anaesthesia in dogs. To reduce the prevalence, more efforts need to be made to prevent loss of body heat before and during core hypothermia, especially in smaller dogs with high ASA physical status, and undergoing thoracic surgeries and diagnostic procedures and lengthy anaesthesias.

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