INVESTIGATIONS OF FLUOTHANE ANESTHESIA IN THE HORSE

by

Ronald Chris Jensen

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INTRODUCTION

General anesthesia in the horse often presents a problem to the veterinary surgeon. He must find an anesthetic agent which is adequate for the operation to be performed, yet not unduly endanger the life of the patient. It must not be prohibitive in its cost and its administration must not be particularly complex.

Because of these reasons there has been a constant search for an ideal anesthetic for the horse.

In 1948, Millenbrick (39) developed a technique of general anesthesia using a combination of pentabarbital sodium, chloral hydrate, and magnesium sulfate, and found it to give good anesthesia with low toxicity and a recovery period of about one hour. In 1950 (36) and again in 1960 (30) thiopental sodium injected intravenously rapidly was found to be a good general anesthetic of short duration in the horse. Anesthesia by inhalation of ether fumes has been tried in numerous methods including a technique described by Reed et al. (44) which utilizes a series of four vaporizers to produce an adequate ether concentration. Hannson and Johannison (25) have experimented with barbiturate-nitrous oxide-succinylcholine anesthesia and concluded that it is not a suitable anesthetic combination for the horse. Cyclopropane in a closed-system has been used for general anesthesia in the

horse (9). Frances and Parry (17) report on the value of beta-naphthoxyethanol as a general anesthetic in the horse. Recently, studies have been made on the combination of promazine, chloral hydrate, and ultra-short-acting barbitrates (19) and on the use of intravenous ether (18) in producing general anesthesia for equine surgery.

However, with the possible exception of the pentabarbital sodium chloral hydrate, and magnesium sulfate combination, none of these anesthethia techniques have come to be routinely used by the practicing veterinarian, and it is apparent that the search for the perfect equine general anesthetic must continue.

In these studies on various anesthetic agents, it became apparent that inhalation anesthetics had certain advantages. Among these advantages was that the depth of anesthesia could be rather easily varied, respirations could be assisted if necessary, and continuous oxygenation could be insured (55). Because the anesthetic depth could be varied according to the need, animals could be kept anesthetized for longer periods of time, allowing the surgeon to work in a more relaxed manner and making it easier for both the surgeon and the patient.

Inhalation anesthesia in the horse is not a new procedure, but until recently the only inhalation methods used to any extent were open-drop chloroform and ether in various closed systems. In December of 1956, Raventos (43) described the

action of Fluothane[1], a new volatile anesthetic. Since that time there have been reports of its use in the horse (7, 11, 14, 16, 28, 29, 31, 52).

The purpose of this study was to develop a technique for administering Fluothane to the horse and to show that Fluothane is a safe and practical general anesthetic which may be used for various surgical procedures.

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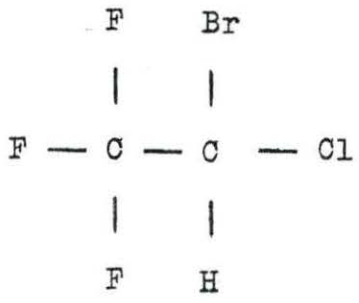
[1]Imperial Chemical Ltd., England.

REVIEW OF LITERATURE

The physical and chemical properties of Fluothane have been well described (6, 23, 26, 37, 43, 47). It is halogenated ethane, with a chemical formula of 2-bromo-2-chloro-1:1:1-trifluorothane ($CF_3CHClBr$) and a structural formula:



Fluothane is a liquid with a specific gravity of 1.86 at 20 degrees C., and its boiling point is 50.2 degrees C. at 760 mm. Hg. Its vapor pressure at 20 degrees C. is 343 mm. Hg. It has a characteristic but not unpleasant odor which is difficult to define. Like most heavily fluorinated hydrocarbons, Fluothane is not inflammable and its vapors mixed with oxygen in proportions from 0.5 per cent to 50 per cent (v/v) are not explosive. Fluothane decomposes slowly with the formation of volatile acids when exposed to light; it is stable if stored in amber colored bottles. Thymol in the proportion of 0.01 per cent w/w added to Fluothane stabilizes the anesthetic to the action of light.

Fluothane is stable when in contact with soda lime. When

its vapors mixed with 5 per cent carbon dioxide plus 95 per cent oxygen saturated with water, were recirculated for 2 hours in a closed system containing soda lime kept at 50 degrees C., taking care to replace the carbon dioxide absorbed by further additions of this gas, there was only 0.02 per cent decomposition as indicated by the increase in the halide of the soda lime. Its decomposition has also been studied in experiments on anesthetized dogs using a closed-circuit method and found to be nil. These two sets of experiments show that Fluothane is stable in contact with soda lime and that it is possible to use it in closed-circuit methods of anesthesia without the formation of toxic decomposition products (43). However, Hudon et al. (26) state that it is a stable compound but theoretically, when exposed to air, moisture or light, it may in time break down into various acids of the halide group. The decomposition products may affect certain metals, such as tin and aluminum. Liquid Fluothane may attack rubber, producing softening and swelling. The rubber reverts to normal when withdrawn from the Fluothane. Clinically, the decomposition products have no toxic effects even though they are theoretically harmful.

Fluothane should not be confused with Fluomar (trifluoroethyl-vinly ether), an inflammable fluorinated ether with somewhat different properties (6).

Raventos (43), using mice, computed the anesthetic

coefficient 50 (a.c.50) and the lethal coefficient (l.c.50) of Fluothane. Other common inhalation anesthetics were computed by the same author. He found the a.c.50 for Fluothane was lower than all others except trichlorethylene. The l.c.50 to a.c.50 for Fluothane was 3.3 as compared with 1.7 for ether and 1.5 for chloroform. However, Krantz et al. (33) disagree with these findings and report that the anesthetic indexes determined in mice, dogs, and monkeys showed that Fluothane exhibited a low margin of safety.

There are also conflicting reports in the literature concerning the analgesic properties of Fluothane. MacKay (38) reports poor postoperative analgesia in man, whereas Junkin et al. (32) have found it to be a good analgesic, at least in pediatric surgery. In dogs, Sims (46) also reports that in a light plane of anesthesia, Fluothane is not a good analgesic.

One study (1) reports that lack of cutaneous anesthesia seems to be one of the peculiarities of Fluothane.

Several types of apparatus have been used to administer Fluothane to the horse (15, 16, 27, 28, 50, 51, 55). Basically, they are similar, in that they are usually of the closed type, either a circle absorber or a to-and-fro apparatus. Most reports seem to favor the closed, circle type system, primarily because of economics. That is, this system is used to conserve the Fluothane vapors. An additional advantage of a closed circuit is the conservation of body

heat (27).

In general the basic constituents of a closed system apparatus consists of a source of oxygen (and occasionally nitrous oxide), a vaporizer, a carbon dioxide absorber, and a rebreathing bag.

Vaporizers used are of several different types, ranging from uncalibrated to controlled percentage types. Although calibrated vaporizers offer some advantages they are not essential to safe Fluothane anesthesia (29). Clinical assessment of depth of anesthesia is far more important and reliable than exact knowledge of vapor concentration (46). In man, numerous vaporizers have been used in Fluothane anesthesia such as the trilene bottle (3), Toregger, Heidbrink, and McKesson vaporizers (6), the Fluotec vaporizer (32), the Rowbotham bottle (38), and the F.N.S. Fluothane vaporizer (13). Most of the more recent literature on human Fluothane anesthesia indicate a trend toward using the controlled percentage type vaporizer.

Carbon dioxide absorption is necessary in any system in which rebreathing occurs for more than a few minutes. This may be accomplished either by soda lime or baralyme. Soda lime is a mixture of 90 per cent calcium hydroxide with 5 per cent sodium hydroxide with silicates to prevent powdering. Baralyme is 80 per cent calcium hydroxide with 20 per cent barium hydroxide (28). Baralyme is less caustic and produces

less heat than soda lime (34). Stephen et al. (48), in a test of toxicity, could find no evidence of decomposition of Fluothane even after 14 days of constant vapor contact with baralyme which was heated periodically to 50 degrees C. during the exposure. Raventos (43) in his experiments shows that Fluothane is stable in contact with soda lime and that it is possible to use it in closed circuit methods of anesthesia without the formation of toxic decomposition products.

Most preparations of either soda lime or baralyme contain an indicator which changes color when the absorptive capacity is depleted.

Rebreathing bags adequate for the size of the horse anesthetized are used in the closed circuit anesthesia.

The most common methods of inducing anesthesia in the horse, are by intravenous short acting barbiturates or by the use of Fluothane alone. Rapid injection of short acting barbiturates seems to be the most popular method (14, 16, 27, 28, 31, 51). Various products or combination of products have been reported. Jones et al. (31) has used a mixture of pentobarbital sodium and thiopental sodium, thiolbarbitone sodium, and thiamylyl sodiu. Fisher and Jennings (16), Tavernor (51), and Jennings (27) report using a ten per cent solution of thiopentone sodium.

The whole dose of barbiturate has been given rapidly to the standing animal and the subject sinks into light anesthesia

within 15 seconds (27).

Fluothane is potent enough to induce anesthesia in the horse when used alone (14, 16, 52). This may be with (16) or without (14, 52) preanesthetic sedatives. When Fluothane is used for induction, a close-fitting face mask is applied to the horse and then connected to the anesthetic machine. Anesthesia is then begun. Fisher and Jennings (16) report that Fluothane alone may produce anesthesia in five to six minutes. Excitement and struggling are negligible during this period. They further state that the advantage of inducing with Fluothane is that rapid reversibility is possible throughout all stages of anesthesia. Sims (46) believes that induction and maintenance of anesthesia with Fluothane alone in the dog, is in most cases preferable since in this way all the advantages of the drug are preserved.

The concentration of Fluothane necessary for induction has been reported as approximately two per cent by Vasco (52). Tavernor (51) states that initially, Fluothane may be supplied from the vaporizer at about 1.5 per cent, then the concentration should be increased slowly to about five per cent in order to bring the concentration to a suitable level to maintain anesthesia. The percentage of Fluothane necessary for inducing Fluothane anesthesia in man is reported as two per cent by some investigators (32, 38, 54). Others report three per cent (13) and 3.5 per cent to 4.0 per cent (48). One

study (1) used a concentration of 1.60 per cent to 1.0 per cent because this decreased the fall in blood pressure associated with Fluothane induction. The concentration used for induction in laboratory animals (dogs and monkeys) was 1.5 to 2.5 per cent in one study (49) and two to four per cent in another (43).

Induction in man has been found to be smooth, rapid, and free from coughing, secretions, and excitement (5, 26, 48). Fluothane has been used alone or with the aid of short acting barbituates (3, 6, 12, 31, 38). This drug is sufficiently potent that anesthesia can be induced using the open drop method in humans (32, 38, 48). Succinylcholine chloride has been used in conjunction with thiopental sodium for induction in one study (3).

In the horse a preanesthetic tranquilizer, usually of the phenothiazine derivative type is generally administered prior to induction (16, 27, 28, 31), especially if rapid injection of barbituates is used in the induction process. Jones (28) and Jones et al. (30) state that the value of the preanesthetic sedation used in this rapid induction technique cannot be overemphasized since it reduces or abolishes induction and emergence excitement, facilitates the maintenance of an even degree of anesthesia, reduces the amount of anesthetic required, and increases the margin of safety. However, this may not always be the case since some authors fail to use any

preanesthetic of any kind (14, 16). Recovery has been reported to be slowed by the use of preanesthetic sedatives (16, 51).

Regarding the subject of preanesthetics in Fluothane anesthesia in humans, it is reported those used are not different from those currently being used with other general anesthetics (26). Some of the more commonly used drugs are Demerol, codeine, Benadryl, Phenergan, Larcjactil (3), opiates and scopolamine (38), atropine (10), morphine (45), and meperidine (5). One author (38) states that the type of preoperative medication seems to have little effect on either induction or maintenance of anesthesia.

Singleton (47) and Lumb (37) report the use of various drugs as preanesthetics prior to using Fluothane. In another study, Sims (46) states that there is no need for using preanesthetics with Fluothane.

The use of atropine sulfate in horses as a preanesthetic has also been reported (29, 31, 51, 52) to reduce secretions and eliminate cardiac irregularities. In one study (52) four horses were given atropine sulfate intravenously at a level of 0.1 g. per 100 pounds of body weight over a one minute period, during Fluothane anesthesia. Within two minutes all four of the horses had an increase in heart rate on an average of five (four to seven) beats per minute. The peripheral pulse pressure rose on an average of only 1.5 mm. All arrythmias disappeared and did not return during the rest of the anesthetic period.

In another study on the effect of atropine in the dog, Hall and Norris (23) found in those dogs given intravenous atropine (0.053 mg. per Kg.) prior to induction, there was a greater decrease in heart rate and blood pressure than in nonatropinized animals. Premedication with atropine in man is believed by some (1, 32, 48) to be important because it tended to minimize the incidence of bradycardia. Severinghaus and Cullen (45) found circulatory depression to be less pronounced after atropine. Chang et al. (6) in a study on 120 human subjects found that atropine will tend to minimize the initial induction hypotension, but it is probably of value mainly in the older age group. Atropine was found to rapidly abolish bradycardia and hypotension in man when administered during Fluothane anesthesia (5, 42).

Campbell and Lawson (4) have described the signs of anesthesia commonly seen in general anesthesia of the horse. In Fluothane anesthesia in the horse, the state of anesthesia is conveniently assessed by observation of the respiratory rate and the eye reflexes. As anesthesia lightens the respiratory rate increases, and the palpebral reflex and nystagmus reappears. Once nystagmus appears the anesthesia further lightens very rapidly (51). Slowing of the heart rate is also an indication of increased anesthetic depth (29).

In the dog, one investigator (49) found that the decrease in blood pressure was so consistent that the degree of hypo-

tension could be considered a measure of the depth of anesthesia. Other studies (46, 47) report the anesthetic depth can be judged by the amount of moisture on the tongue and the relaxation of the anus.

Deepening anesthesia in man is related to the respiratory and cardiovascular system (48). Signs, in general, are the same as ether, except they occur more quickly. One of the most important single signs is related to respiration. With deepening anesthesia, the intercostal muscles are paralyzed and the level of anesthesia can be followed accurately by the character of respirations (1). Hudon et al. (26) found that the pupils remain small and do not dilate progressively as they do during deep anesthesia with ether. Given et al. (21) noted that the usual predominance of the intensity of the first heart sound over that of the second frequently may be reversed during anesthesia produced by Fluothane, the intensity of the second sound becoming greater relative to the first sound. They concluded, however, that in preliminary attempts to employ the changes in heart sounds during Fluothane anesthesia as a guide to anesthetic depth have been unsuccessful.

Fluothane anesthesia depresses the cardiovascular system and may produce some cardiac irregularities. Pulse rates of a horse under Fluothane is reported by Jones et al. (31) to be relatively constant between 55 and 70 beats per minute

(mean 65, range 48 to 128). Vasko (52) reports a decrease in pulse rate in four atropinized horses from 30 beats per minute to an average of 18 beats per minute over a six minute period. He also found a decrease from 28 beats per minute to 12 beats per minute over a period of three minutes in eight horses not receiving atropine as a preanesthetic. Various arrhythmias and cardiac irregularities have been noted in the Fluothane anesthetized horse. Vasko's study reports nodal rhythms, ventricular tachycardia, and varying degrees of arrhythmia in seven of 12 horses during a 30 minute period. During the period between these exacerbations a pronounced bradycardia was noticed. Also in this study a brief period of supra-ventricular arrhythmia was observed in the early stages of anesthesia. Another author (31) noted tachycardia and cardiac arrhythmias are common during painful stimulation of an inadequately anesthetized horse.

Hypotension is often associated with Fluothane anesthesia. A study of such hypotension was made by Vasko (52). In horses pretreated with atropine, he found femoral artery pressures decreased slowly from an average of 160 (155-163) to an average of 70 (69 to 72) over a six minute period, indicating a marked degree of hypotension. In those horses receiving no premedication of atropine, the femoral arterial pressure dropped from an average of 150 (140 to 158) at the onset to an average of 68 (66 to 74). This occurred over a period of

six minutes and did not seem to be coordinated with changes in heart rate.

In human medicine there is also a reduced pulse rate in Fluothane anesthesia reported (6, 16). In two other studies (20, 38) the effect on pulse rate was found to be not consistent.

Hudon et al. (26) report a 20 per cent decrease in blood pressure of man when anesthetized with Fluothane. This hypotension is related to the depth of anesthesia and is found to be reduced in intensity as anesthesia is prolonged and thereafter the blood pressure remains only slightly below normal. Upon recovery the blood pressure remains exactly as if the patients had not been anesthetized. Similar findings are reported by other authors (5, 6, 20, 42). Other workers (3) report that hypotension is to be expected during Fluothane anesthesia. They further state that the difficulty presented by hypotension induced by Fluothane may be overcome, but peripheral circulatory depression is a most serious impediment to unconditional acceptance of Fluothane. MacKay (38) observed hypotension in 56 of 203 cases. In some normally hypertensive patients there was a drop as much as 60 mm. of Hg. He also states that extreme variation in blood pressure was the most striking and troublesome complication of Fluothane anesthesia. Chang et al. (6) report that in severe hypotension episodes in which there appeared to be a cardiac

standstill, inflation of the lungs with 100 per cent oxygen rapidly restored both blood pressure and pulse within a minute. Ausherman and Adan (1) find very little fall in blood pressure, provided the Fluothane is introduced slowly. Pittinger et al. (42) agree that hypotension does not appear to be sufficiently severe to limit the general use of the drug.

Hudon et al. (26) also have reported on the cardiac irregularities during Fluothane anesthesia of man. They state that with Fluothane, vagal action on the heart predominates. This predominance increases the movement of the pacemaker and contributed to the occurrence of a nodal rhythm. Depression of the sino-auricular node may cause discharges from ectopic centers. These arrhythmias occur during rapid induction and during deep stages of anesthesia. They disappear if the concentration of Fluothane is decreased and hypoxia, if present, corrected. These irregularities were present in 14 per cent of the patients anesthetized with Fluothane in this study. Clinical arrhythmias were reported in eight per cent of the patients in another study (1). Chang et al. (6) found irregularities in 17 of 120 patients usually in the form of extrasystoles. In MacKay's (38) study there were cardiac irregularities in six of 203 cases, three of which were cardiac surgical procedures. Gain and Paletz (20) found cardiac irregularities in six of 22 cases and classed them as follows: two isolated ventricular extrasystoles, one pulsus bigiminus,

one ventricular tachycardia, one nodal rhythm, and one peculiar sinus coupling. They further report that these irregularities were not always rapidly reversed by lightening the anesthesia. In one study (48) all arrhythmias (12 of 30 cases) reverted spontaneously with lightening the plane of anesthesia or with improved ventilation. In this report, preoperative arrhythmias did not become more serious under Fluothane anesthesia. In still another study (5) on this matter, cardiac arrhythmias did not appear to be more frequent than with the other general anesthetic agents commonly used.

There are reports in the human literature of increased venous pressure (6, 45) and of reduced pulse pressure (1). This reduction in pulse pressure is also seen in the dog and monkey (49). There is also a report (23) in the literature of a net increase in pulse pressure when induction was accomplished slowly in the dog.

The effect of Fluothane on the cardiovascular system of the laboratory animal has also been studied. Raventos (43) finds a decrease in the heart rate of all animals observed. During the induction period in dogs, a reduction from 130-170 to 80-100 beats per minute was recorded, but the heart rate rose again to about 120-140 beats per minute shortly after the beginning of inhalation of maintenance concentrations. In a study (23) in dogs the heart rate decreased about ten per cent during induction. Electrocardiographic arrhythmias were

uncommon with Fluothane administration in dogs and monkeys, but nodal rhythms and ventricular arrhythmias were occasionally seen (49). Usually these arrhythmias were associated with deep levels of anesthesia and disappeared spontaneously when Fluothane concentration was reduced. Hall and Norris (23) found only one arrhythmia of any type in a total of 43 inductions in nine dogs. They also observed that no severe arrhythmias occurred until long after respiratory arrest and a dog with complete apnea and no blood pressure still exhibited a normal electrocardiogram. Concerning the electrocardiographic tracings, Raventos (43) observed no irregularities either during induction or maintenance, although he noted a decrease in voltage of the whole QRST complex but no irregularities when apnea was produced. Under surgical anesthesia the T-wave was strongly inverted (33).

Hypotension in laboratory animals was found to be roughly proportional to the concentration of Fluothane vapors, the largest fall occurring during induction and reached its maximum about 30 to 40 minutes after the beginning of anesthesia (43). Hall and Norris (23) noted that dogs did not exhibit severe hypotensions. Singleton (47) agrees that the hypotension effect of the drug is not a problem in canine surgery. Stephen et al. (48) state that hypotension was almost invariably seen with the onset of the third stage of anesthesia.

Cardiac arrest in man under Fluothane anesthesia has been reported (5, 6, 26, 48). These authors report a combined total of six cases, none of which were fatal, and in only one (5) instance was an overdose of Fluothane said to be the direct cause.

The mode of action of Fluothane on the cardiovascular system is not definitely known. There appear to be two schools of thought, some believing this action is due to direct myocardial depression, while others feel it is because of a ganglionic blocking action. Gain and Paletz (20) state that the bradycardia and hypotension appear to be the result of direct myocardial depression and that it is rare to find such profound circulatory collapse, as was seen in their studies, in young robust males with ganglionic blockers. In another work (6) it was found that an increase in the concentration of Fluothane would cause myocardial depression, but the degree of myocardial depression and depth of anesthesia did not seem necessarily related. Severinghaus and Cullen (45) report that the cardiovascular effects were due primarily to myocardial depression and that the circulatory depression could not be due to ganglionic blockage. Studies (23, 33) on dogs anesthetized with Fluothane suggest a ganglionic action rather than a cardiotoxic or even a vasomotor center of action. Stephen et al. (48) found that patients anesthetized with Fluothane appear to be unusually sensitive to bleeding; in

this way they resemble patients rendered hypotensive by ganglionic blocking drugs. Raventos (43) states that in laboratory animals the probable cause of hypotension is due to sympathetic ganglionic block.

Fluothane is a respiratory depressant also. Jones et al. (31) and Vasko (52) have reported on the respiratory rate of horses anesthetized with Fluothane. Jones found this rate to be about seven to nine per minute when the degree of anesthesia was satisfactory. In eight horses he observed respiration throughout the anesthetic period and found a range in respiratory rate from 0 to 14 per minute. Vasko reports the respiratory rate to be five to six per minute in surgical anesthesia. Fisher (14) finds a depression of the ventilation rate in horses under Fluothane anesthesia, and associates plasma pH and plasma carbon dioxide changes with this lower ventilation rate. Short periods of apnea in the horse are reported by Tavernor (51). He also reports some breath holding if the concentration of Fluothane is too high when it is being used for induction. These periods of apnea were easily controlled by artificial respiration. Breath holding was also observed in dogs and monkeys during induction (49).

The rate and depth of respirations are depressed in Fluothane anesthesia of man (1, 6, 8, 26, 32, 38, 48). Hudon et al. (26) found that while rate and depth of respirations are depressed, central respiratory reflexes were not abolished.

One author (8) reports that the respiratory rate was significantly elevated during both light and deep levels of anesthesia. The same author found the elevations of carbon dioxide tensions were significant at the moderate and deep levels. Carson et al. (5) state that Fluothane is a potent respiratory depressant, particularly in deeper planes of anesthesia and that while this is undesirable, it is not an insurmountable drawback.

Chang et al. (6) report that when anesthesia became light in man, breathing became faster and shallower causing a progressive decrease in tidal and minute volumes. Stephen et al. (48) felt that the decrease in minute volume in surgical planes of anesthesia was due to depression of the respiratory center. There is one study (8), however, that reports no significant change in respiratory minute volume during any stage of anesthesia. They did find that tidal volume was depressed to a significant degree during both light and deep planes. The reason given for the fact that minute volume did not fall with tidal volume was a result of the large increase in respiratory rate. Another study in man (21) found depression of the tidal volume of respirations to as low as 50 cc. to 100 cc. with the concurrent onset of tachypnea to occur with considerable regularity.

In dogs (23) tidal air is reported to be depressed more than respiratory rate. Minute volume was decreased 15 per

cent in light Fluothane anesthesia and up to 60 per cent in deep anesthesia.

In laboratory animals (43), both the amplitude and frequency of respiratory movements were decreased during Fluothane anesthesia. The reduction in respiratory rate was, as a rule, more than reduction in amplitude. This study also declares that respiratory arrest produced by Fluothane was easily reversible and normal respiratory movements were usually present after a few minutes of artificial respiration. In a clinical study (37) in the dog, apnea frequently developed, particularly on induction. This apnea was reversed by emptying the system of anesthetic agent and manually inflating the lungs with oxygen for a short time. Hall and Norris (23) took five dogs to apnea and then resuscitated them. However, Krantz et al. (33) report that in their experiments they frequently encountered difficulties in resuscitating animals which were brought to respiratory arrest with Fluothane. The rate of respirations in the dogs and monkeys is slowed with increasing depth of anesthesia (49). There is a diminution in tidal volume associated with the slowing of the rate. Progressive respiratory depression occurs in the third stage of anesthesia. In another study (23) on dogs the respiratory rate was reported to be essentially unchanged under light Fluothane anesthesia,

but in deep planes the rate was decreased almost 40 per cent.

In cases of overdose of Fluothane, respiratory arrest is reported to precede cardiac failure by several minutes in both man (48) and animals (30, 37, 47).

A study of plasma pH and plasma carbon dioxide of various species, including the horse, under Fluothane anesthesia was conducted by Fisher (14). He observed that Fluothane anesthesia produced a fall in ventilation rate. A lowering of the pulmonary ventilation caused carbon dioxide retention and a raising of plasma carbon dioxide content. It was observed that in prolonged periods of anesthesia there was often a stabilization of the plasma carbon dioxide content at a higher concentration than normal and, towards the end of anesthesia, a tendency for the carbon dioxide concentration to fall. The changes taking place in the plasma pH during Fluothane anesthesia are consistent with carbon dioxide retention and a respiratory acidosis. The plasma pH often returned to the preanesthetic value before the plasma carbon dioxide content returned to the control value. It was inferred from this that perhaps some extra buffering capacity or buffering regulating mechanism which has previously been inhibited by the anesthesia came into action after recovery.

In a study (23) of plasma pH and plasma carbon dioxide in the dog in light Fluothane anesthesia the plasma pH was 7.31, and the plasma carbon dioxide was 44 per cent, whereas

in deep Fluothane anesthesia the pH decreased to 7.16 and the plasma carbon dioxide increased to 52 per cent. It is interesting to note the effect of Fluothane anesthesia on asthmatics reported in the human literature. Carson et al. (5) say they have been impressed clinically with the ease with which Fluothane is tolerated by the asthmatic. Ausherman and Adan (1) anesthetized eight known asthmatics with Fluothane. None exhibited stridor or spasm of the larynx or bronchi. Patients with emphysema accompanied by venous hypertension seemed to improve temporarily while under anesthesia and for some time after (26). In another report (6) in one patient with preoperative bronchospasm, the bronchospasm disappeared after five minutes of Fluothane and did not return for several hours postoperatively.

Fluothane is also used in other types of poor risk patients (5, 42, 48). In one study in dogs, the author (47) noted an improvement in the pulse and respiration of almost all poor risk cases as soon as they are fully anesthetized with Fluothane.

The per cent of Fluothane concentration necessary for the maintenance of anesthesia in the horse was not noted in this review of literature. In dogs and monkeys it is reported to be 0.5 per cent to 1.5 per cent (49). In another study (43) dogs premedicated with morphine or thialbarbitone required 0.8 per cent while unpremedicated dogs required from 1.0 per

cent to 1.2 per cent. Various authors used different concentrations to maintain anesthesia in man. One reporter used 0.4 per cent to 1.5 per cent (13) while another used 0.6 to 1.0 per cent (3). Another reports that two per cent was required for almost all patients (32), and one invariably used only one per cent (3).

A notable feature of maintaining anesthesia with Fluothane is the lack of secretions. In man salivary and tracheobronchial secretions are reported to be decreased or inhibited (1, 5, 26, 32). One report (6) states there was no increase in secretions noted. Stephen et al. (49) found a lack of salivary secretions in dogs and monkeys. Singleton (47) observed a suppression of salivary, bronchial, and gastric secretions. Sims (46) states that excessive mucus and salivation are absent so that no premedication is required in that regard. In cattle, however, Fisher and Jennings (16) found there is no inhibition of salivation during Fluothane anesthesia.

There appears to be reduced bleeding under Fluothane anesthesia of man (1, 6, 26). This phenomena does not seem to depend on hypotension because bleeding was minimal when the blood pressure was near the preoperative level. A study on dogs also reports reduced capillary seeping although venous dilation is marked (47).

Some feel that Fluothane may have anti-shock activity

(26). Even with profound hypotension, little evidence of shock was seen by clinical observation. Perhaps a combination of decreased oxygen consumption and lack of sympathetic over-activity are responsible for the absence of clinical signs of shock (45). This anti-shock activity was also noted in three reports on dogs under Fluothane anesthesia (37, 46, 47).

Muscle relaxation in the horse under Fluothane anesthesia has been reported as good (16, 31). Adequate muscle relaxation has been obtained for various types of operations including bone pinning and laryngeal ventriculectomy. However, Hall (24) states that while **Fluothane** anesthesia usually provides good muscular relaxation, it was sometimes impossible to produce completely satisfactory relaxation of the abdominal musculature while the patient is breathing spontaneously. Therefore he recommends the use of relaxant or a regional nerve block in these procedures. In human surgery, Fluothane gives good muscular relaxation except in upper abdominal operations where the relaxation is not always satisfactory. Adequate relaxation for these procedures may be secured only at a cost of marked hypotension or cardiac arrhythmia by using Fluothane alone (5, 26, 42). In a review of 47 cases requiring pronounced relaxation, in only four was it necessary to use a muscle relaxant (49).

Uterine musculature relaxation to a troublesome degree has been reported in nine vaginal deliveries under Fluothane.

A decrease in concentration of Fluothane seemed to correct this (38). Another author (10) has found the Fluothane to have a definite inhibitory effect on the contractility of the uterus with complete or almost complete obliteration of the contractions.

Considerable relaxation, to the point that the use of muscle relaxants is almost superfluous except for intrathoracic surgery in dogs is reported (46, 47). Lumb (37) found muscle relaxation to be adequate for all major abdominal and thoracic canine surgery.

Succinylcholine chloride has been found to be well suited to anesthesia with Fluothane (1, 5, 6, 26, 32, 38, 48). Most of these same authors also report that the use of curare is not recommended for Fluothane anesthesia. In dogs succinylcholine chloride exerts its usual action when used with Fluothane, but in some dogs, administration of d-tubocurarine chloride was associated with a profound hypotension, whereas in other animals little if any disturbance of the blood pressure occurred (49).

One of the reported advantages of Fluothane anesthesia is its smooth and rapid recovery. The recovery time varied from 15 to 330 minutes in one study (31) to 30 to 45 minutes in another (51). Vasko (52) allowed recovery to take place in a darkened stall and reports an average recovery time of 50 minutes. Others (16, 51) advise hobbles or other forms of

restraint until the horse is able to stand to prevent injury to themselves.

Human patients receiving Fluothane usually awaken more rapidly than comparable cases anesthetized by conventional agents (5). Stephen et al. (48) report recovery from anesthesia to be rapid and remarkably free of excitement, even after prolonged administration. Protective reflexes and movement on demand was present within five minutes. Full orientation as to time, place, and person was present within ten to 20 minutes. Pittinger et al. (42) found that the patient could answer questions coherently on an average of four minutes after the end of the surgical procedure and it was only an additional five minutes average time, until the patient was able to walk to a recovery room. Other reports (1, 26, 32) state rapid and complete recovery with infrequent excitement, nausea and vomiting. Chang et al. (6) found that increasing the duration of anesthesia was associated with an increase in recovery time.

When Fluothane is used in canine and feline surgery, recovery is quick and there are no unpleasant after-effects (41a, 46, 47). Raventos (43) reports that recovery from anesthesia with Fluothane was equally fast and free from excitement in all animal species studied. All animals were completely recovered in about ten to 20 minutes even from periods of anesthesia lasting five to six hours.

Following recovery there is no postoperative mental depression. In human patients who had been anesthetized twice, once with pentothal-nitrous oxide-oxygen and once with nitrous oxide-oxygen-Fluothane, stated that with Fluothane they felt less depressed the next day (26). Stephen et al. (48) also report that post-operative morbidity was minimal.

Because of the high cost of Fluothane it is desirable to use it sparingly and the amount needed for anesthesia is important. Jones reports 30 to 40 cc. per hour of surgical anesthesia in one study (28) and 4.4 ml. per 100 pounds of body weight per hour of anesthesia in another project (31). He also found that the amount used for short procedures was significantly greater than that required for longer operations in horses. This study also states a highly significant difference existed between the amounts of Fluothane required for horses under and over 700 pounds of body weight. In a study (27) of 36 horses averaging 916 pounds anesthetized with Fluothane for an average of 79 minutes, 35.6 cc. was required for maintenance. Fisher and Jennings (16) in 17 horses used 37 cc. per 500 Kg. animal per hour for maintenance and six cc. per minute per 500 Kg. animal for induction.

The average amount used in a report (46) of operations done on 71 dogs and 43 cats was 7.5 ml. for dogs and 2.5 ml. for cats. This report also states that for very short operations in cats, one ml. of Fluothane on a cotton sponge in a

bell jar or a closed mask is adequate.

Hepatotoxicity might be expected in a highly halogenated compound like Fluothane. However, with relatively prolonged exposure of animals to chloroform or Fluothane under similar circumstances, the degree to which the liver was spared with exposure to Fluothane when compared to chloroform was remarkable (49). In repeated anesthesia in rats using Fluothane, no gross or histological changes in their livers, kidneys, and brains (33). Bromsulphalein retention following Fluothane anesthesia in dogs was almost identical to that following ether anesthesia (54).

Carson et al. (5) found that liver function tests performed on 14 human patients indicate that as long as hypoxia is avoided Fluothane does not damage hepatic function sufficiently to be recognized by present methods of measurement. In assessing the influence of Fluothane on liver metabolism, Stephen et al. (48) found less disturbance in blood sugar levels than most conventional anesthetic drugs. Other reports (3, 54) indicate no clinical evidence of postoperative hepatic disturbance. Little and Barbour (35) in a study of hepatic function alterations produced by anesthetics found that hepatic functions were not affected more following anesthesia produced by Fluothane than following anesthesia produced by either cyclopropane or ether. Following Fluothane anesthesia cholesterol esterification was normal, alkaline

phosphatase activity was normal, total serum bilirubin concentration, normal, and cephalin-cholesterol flocculation determinations were normal. Serum cholinesterase activity was lowered, but not as much as with cyclopropane or ether concentration. Using thymol turbidity tests Virture et al. (54) found no deleterious effects of Fluothane on the liver.

Virture and Payne (53) also report on a patient that died on the eleventh day postoperatively after Fluothane anesthesia in which death was believed to be due to acute yellow atrophy of the liver and acute pancreatitis. The clinical course was similar to that of chloroform poisoning except that the downhill course did not begin until the sixth day postoperatively.

No signs of any pathological condition of the kidneys (albumin, casts, or abnormal specific gravity) were found in eight cases averaging 4 1/2 hours of Fluothane anesthesia (26). In another report (54) the kidney function of patients as measured by urea clearance tests and other possible metabolic changes as measured by blood volumes seem minimal. In a study on dogs, Blackmore et al. (2) found that there is a correlation between the cardiovascular and renal responses to Fluothane and that in sufficient concentration Fluothane has significant but reversible action on renal activity. In rats there was no alteration of renal function when tested by the water diuresis and phenol red excretion tests (43). The only

kidney alteration found by one author (49) consisted of a minimal and variable dilation of the proximal convoluted tubules without evidence of necrosis or degenerative changes.

Complications of Fluothane anesthesia in the horse, although few have been listed by Jones et al. (31) as, difficult transition from induction to inhalation anesthesia in occasional horses; tachycardia and arrhythmias during surgical stimulation of the inadequately anesthetized horse or during depletion of the carbon dioxide absorbent; occasional overdosing with Fluothane with marked respiratory depression; and temporary postanesthetic extensor dysfunction of one or both hindlegs in occasional horses, probably due to prolonged restraint in an abnormal position.

METHODS AND MATERIALS

In this study, 49 horses were anesthetized with Fluothane a total of 56 times. Forty-four of these horses were anesthetized one time only, three were anesthetized twice and two were anesthetized a total of three times.

The 47 horses anesthetized represented several breeds including Quarter Horse, Thoroughbred, Standardbred, American Saddlehorse, Palamino, Appaloosa, Belgian, and Arabian. Also included were Shetland ponies and one Poly of America (Table 1). The ages of the horses were from 17 days to 12 years with an average of 3 1/2 years. Of the cases studied, 19 were female and 27 uncastrated males, and 10 castrated males.

Thirty-eight of these were clinical cases at the Stange Memorial Clinic, four were Iowa State University experimental horses, and five were experimental horses from the National Animal Disease Laboratory, Ames, Iowa. These horses were anesthetized for various surgical procedures (Table 2), including 16 abdominal procedures, 15 orthopedic operations, five operations on the head or face area, seven removals of superficial cysts and/or growths, two neurectomies, and five procedures of the cervical area. Forty-six of the anesthetic studies were conducted at the Stange Memorial Clinic and ten studies were at the National Animal Disease Laboratory of Ames.

The average duration of anesthesia was 67 minutes and had

an average recovery time of 29.3 minutes. The ranges for the preceding averages were eight minutes to three hours, and 13 minutes for duration; and, eight minutes to 92 minutes for recovery time.

The majority of cases studied were clinical cases and therefore when various phases of anesthesia were studied, no uniform number of animals could be placed in separate groups with equal numbers of control animals. These studies were conducted under actual clinical conditions with the best interest of the patient always being the primary consideration.

Euthanasia was attempted in three horses using Fluothane. In two of these horses, a three year old Shetland pony and an eight month old Standardbred filly, this process of euthanasia was successful. In the third horse, a four year old, 1000 pound gelding, it was impossible to euthanize this horse using Fluothane.

None of the three horses received preanesthetic tranquilization. In the eight month old filly, induction was completed using Fluothane alone. In the other two, succinylcholine chloride was used in the induction process.

Observations made during euthanasia are reported in the results of this paper.

Forty-four of the horses studied were premedicated with

a promazine hydrochloride tranquilizer[1] prior to anesthesia. Thirteen cases did not receive any of this preanesthetic. When it was used the dose of this tranquilizer was two to four mg. per 10 pounds body weight. It was administered intravenously in the jugular vein 30 to 60 minutes before induction.

The effect of this tranquilization prior to anesthesia on induction time, amount of Fluothane used, and recovery time was studied and reported.

The anesthetic apparatus used in this study was a machine constructed for large animal anesthesia.[2] (See Fig. 1 and 2.) The machine was used as a closed system utilizing a rebreathing bag and a carbon dioxide absorbor.

The operating principle of this machine is no different than any other closed system apparatus. Oxygen is supplied to the system from an oxygen cylinder by way of a preset regulator (50 pounds per square inch pressure) (Fig. 3) with a flow meter (Fig. 4). The flow meter is calibrated to give from 0 to 14 liters of oxygen per minute. The oxygen may be directed through the anesthetic vaporizer or it may bypass the vaporizer and enter the system directly. In the majority of cases the vaporizer used was a bubble type, ether vaporizer (Fig. 5) in which 100 to 125 cc. of liquid Fluothane are

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[1]Sparine, Wyeth Co., Philadelphia 1, Penn.

[2]National Cylinder Gas Co., Chicago, Illinois.

placed when the machine is made ready for use. It is not calibrated, but has a series of settings ranging between on and off (Fig. 6).

If the oxygen is directed through the vaporizer, it is first conducted through a small metal tube to the bottom of the vaporizer. Here the tube ends in a porous disc which causes the oxygen to be bubbled through the liquid Fluothane as several small bubbles, and thereby brings about the vaporization of the anesthetic. The anesthetic vapors then pass into the system.

A Fluotec[1] vaporizer was used in anesthetizing 5 horses late in this study (Fig. 5). The Fluotec vaporizer is a controlled percentage vaporizer manufactured specifically for the use of Fluothane. This vaporizer is calibrated to deliver from 1 per cent to 10 per cent Fluothane vapor volume by volume. The calibrations are at 1 per cent intervals. This vaporizer has an automatic temperature compensation value, so that the percentage being delivered is accurate over a temperature range from 55 to 90 degrees F. (38). This then theoretically allows for an accurate percentage concentration to be delivered regardless of oxygen flow or temperature.

The carbon dioxide absorber used was baralyme and was contained in a cylinder sufficiently large to hold in excess

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[1]Cyprane Ltd., England.

of 16 pounds. The average amount of baralyme used in this project was 10 to 12 pounds. The baralyme contains an indicator which causes it to change from its original pink color to a blue color when its carbon dioxide absorbing capacity is saturated.

The inhalation and exhalation tubes carry the anesthetic vapors to the face mask and the expiratory vapors away from the mask are six feet long and made of flexible industrial tubing having an internal diameter of 2.5 inches. The distal ends of these tubes are connected to a Y shaped yoke which has two unidirectional valves. One valve allows the vapors to flow to the horse (inhalation) and the other allows the vapors to flow from the horse (exhalation) (Fig. 7). This yoke is in turn connected to the face mask. The face mask is made of very durable plastic with a rubber diaphragm on one end having a slit-like opening. The other end has a fitting which connects to the yoke (Fig. 8).

During inhalation, anesthetic vapors are drawn from the machine, through the tubing and valves, and into his respiratory system. Upon expiration the respiratory gases, including the anesthetic vapor, are forced through the baralyme where the carbon dioxide is absorbed and back into the system.

Induction of anesthesia was completed by using various drugs and combination of drugs (Table 3). These included

promazine hydrochloride, succinylcholine chloride,[1] and Fluothane; promazine hydrochloride, thiamylal sodium,[2] and Fluothane; promazine hydrochloride and Fluothane; thiamylal sodium and Fluothane; and Fluothane alone.

The actual method of induction was also varied. When succinylcholine chloride was used, its function was to act as a casting agent (40). The calculated dose of 5 mg. per 100 pounds of body weight was injected into the jugular vein of the horse and the horse was allowed to fall to the ground. One of the rear legs was secured in the flexed position with the aid of a side line. The face mask was then placed over the animal's nose and connected the mask to the anesthetic machine.

The same procedure was followed when induction was accomplished utilizing thiamylal sodium. This drug was used only in mature horses and the amount used was two grams in each instance with the exception of one large Thoroughbred in which case three grams were used. The drug was administered by the rapid injection technique described by Jones et al. (30). Fluothane alone (with or without premedication with tranquilizers) was also used to induce anesthesia. In some

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[1]Sucostrin, Squibb and Sons, New York, N. Y.

[2]Surital sodium, Parke, Davis, and Co., Detroit 32, Michigan.

cases the horse was restrained on a tilting, large animal surgery table and in others anesthesia was induced while the horse was standing over a casting area. In those horses restrained on the operating table the mask was merely placed on the horse's face and the anesthetic machine turned on. However, when the horses were standing, it required four or five men to hold the horse still while it was being anesthetized. The mask was first placed on the nose of the horse to allow him to become accustomed to it. When he would stand quietly, the mask was connected to the anesthetic machine and vaporization was begun. After inhaling the anesthetic fumes for two or three minutes the horse would begin to stagger and the men would have to hold the horse up as long as possible. Then they would allow him to sink to the floor.

The method of initiating Fluothane anesthesia regardless of the type of induction was to run both the vaporizer and the oxygen valve at full capacity (14 liters of oxygen per minute) until the rebreathing bag was approximately half full. The oxygen flow was then reduced to two liters per minute and continued at this rate until it was evident that surgical anesthesia was being attained. At this time the vaporizer was turned off. The animal was allowed to breath this mixture and the stage of anesthesia was evaluated. More Fluothane was then vaporized as indicated by the signs of anesthesia.

There were no signs of anesthesia which were character-

istic for all cases. Those signs used in this study were the eye reflexes, the anal reflex, respiration rate, and degree of tail and limb relaxation. The signs were not consistent for each individual animal, and a composite of all signs were necessary to indicate the plane of anesthesia.

When induction was complete the time required for the induction process was recorded on the anesthesia record. Induction time was considered as the time elapsing between the moment the anesthetic apparatus was connected to the face mask and the time at which a stage of surgical anesthesia was reached.

Once anesthesia had been induced, the majority of horses were maintained by using a tight fitting mask although an endotracheal tube was used in a few cases. Both methods were quite satisfactory.

Throughout the maintenance period, periodic vaporizations were required to maintain surgical anesthesia. Also during this period, various observations and measurements were made and recorded.

On a few occasions, the author was both the anesthesiologist and the surgeon. While this did not allow for the most accurate observations and recordings, it was, however, a good test to see if a veterinarian, alone in the field, could incorporate this anesthetic technique into his practice.

Throughout the anesthetic period the pulse rate was

monitored by using a stethoscope over the heart area. The rate was recorded as was any change in character of the heart beat which was noted. If for some reason, such as surgical drapes being over the chest area, it was not possible to use the stethoscope, the pulse rate was determined by digital palpation of the external maxillary artery. Such monitoring of the pulse rate and heart sounds was done every five or ten minutes during anesthesia.

In seven horses, the heart rate and electrocardiogram were visually monitored by using a oscilloscope monitor.[1] In these cases the heart was also checked periodically with the stethoscope.

Electrocardiogram tracings were made on a total of nine anesthetic periods of four experimental horses. The standard limb leads were used (Fig. 9). The area of the limbs on which the plate electrodes were to be placed were clipped and covered with an electrode paste. An electrode was placed on each limb and secured in place by a one inch rubber strap. The tracings were made at various speeds; the most often used speed being 10 mm. per second.

Seven of the electrocardiagrams were made using a six channel, direct recording machine, (Fig. 10)[2] and two were

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[1]Sanborn model 760 monitoring system, Sanborn Co., Waltham, Massachusetts.

[2]Sanborn 350 series, Sanborn Co.

made on a single channel, portable machine.[1]

Venous and arterial blood pressures of four anesthetized horses were recorded during the anesthetic period. The method of recording these blood pressures was as follows. Permanent catheters were placed into the jugular vein and carotid artery of experimental horses several days before the date of recording. The catheters were made of polyvinyl plastic and were approximately 12 inches long. They had an outside diameter of 0.088 inches and an inside diameter of 0.044 inches. On the ends of the catheters which protruded from the vessels were affixed an adapter and a valve. When the blood pressures were to be recorded, another polyethylene tube was connected to the valve (Fig. 11). The opposite end of it led to physiological pressure transducers[2] (Fig. 12). The tube from the carotid artery led to a transducer with a pressure range from minus 400 to plus 400 mm. of Hg., while the tube from the jugular vein led to a transducer having a range of minus 40 to plus 40 mm. of Hg. The plastic tubes were filled with a heparinized saline solution. The transducers were connected to the six channel direct recording machine mentioned earlier and the pressures were recorded. This recording machine is electronically calibrated so that the base line would equal 100 mm. Hg

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[1]Sanborn 100 series, Sanborn Co.

[2]Sanborn model 267B.

for the arterial pressure and 20 mm. of Hg for venous pressure. Blood pressure could then be read directly from the recording machine.

In six horses, blood samples were drawn at various times during anesthesia to study the effect of Fluothane on the blood cells. Samples were drawn from the jugular vein using a 16 gauge, one inch needle, and were collected in oxalated blood tubes. They were usually taken prior to induction and at different times during the anesthetic period.

The samples were taken to the clinical laboratory where hemoglobin determination, a total erythrocyte count, a total leucocyte count, and a differential leucocyte count was made.

Blood gas determinations were conducted in three other experimental horses. Arterial and venous blood samples were drawn from permanent polyvinyl catheters, inserted in the carotid artery and jugular vein, at various times during anesthesia of these horses. Determinations of the carbon dioxide, oxygen, and other gases (predominantly nitrogen) were then run according to the method of Peters and Van Slyke (41b). The concentrations of these gases are reported as volumes per cent.

Respiratory rates were recorded every five or ten minutes in the anesthetized horses to observe the effect of Fluothane anesthesia on the rate of respiration. A respiratory rate of the horse was also taken prior to anesthesia and recorded.

This prerate was taken after premedication if any was used. If any respiratory difficulty or abnormality occurred during the anesthetic period it was noted on the anesthetic record.

Tracings of the respiratory rate were made in six horses under Fluothane anesthesia. This was accomplished by inserting a length of rubber tubing under the face mask of the anesthetized horse. This tubing was connected to a Sanborn model 267B physiological pressure transducer which in turn was connected to the Sanborn 350 direct recording machine on which the tracings were made.

Recovery of the anesthetized horse took place in three different areas. Some were allowed to recover out-of-doors on a turf area. Others recovered on rubber mats in the surgery room, while still others were moved to a box stall and left to recover unattended. Those that recovered on the turf area were always watched and attended by some person.

The recovery time of each animal was recorded. It was considered as the time from when the horse was disconnected from the anesthetic apparatus until the horse would rise without assistance. Observations were made on the effect of the different recovery areas on the recovery time. The effect of preanesthetic tranquilization and duration of the anesthetic period on recovery was also studied.

In a few cases the anesthetic system was cleared of the Fluothane fumes at the end of the surgical procedure by flush-

ing the rebreathing bag with pure oxygen seven or eight times. The horse was then allowed to breath pure oxygen for five to ten minutes. The effect of this procedure on the time required for recovery was noted.

Because Fluothane is a rather expensive drug the amount of this anesthetic required for the anesthesia period is important. In this study records were kept on the amount of Fluothane used in each case. This amount was determined by subtracting the amount of Fluothane in the vaporizer at the end of the anesthetic period from the amount in the vaporizer prior to induction. No attempt was made to distinguish between the amount used for induction and the amount used for maintenance but rather the sum used for the entire procedure was recorded.

The anesthetic periods were placed into groups according to the duration of anesthesia, and the average amounts used by each of the groups was compared. There were five time groups. They were: 1. less than 30 minutes, 2. 30 to 60 minutes, 3. 60 to 90 minutes, 4. 90 to 120 minutes, and 5. 120 to 150 minutes.

There is also a comparison made of the amount of Fluothane used in horses which were premedicated with tranquilizers and those receiving no premedication. This comparison was made in horses anesthetized for similar periods of time in order to minimize the effect of the duration of anesthesia on the amount used.

RESULTS

Induction

Induction of anesthesia presented no particular difficulties in this study. All of the various methods used proved to be satisfactory.

The average induction time in all cases in which induction time was recorded was 4.09 minutes. The range of all cases was from one minute to 14 minutes. The ether vaporizer bottle proved to give a more rapid induction than did the Fluotec vaporizer. The average time when using the ether bottle was 3.72 minutes for 50 cases, whereas the average time for the Fluotec vaporizer was 8.75 minutes in five cases. This difference in induction time was probably due to the fact that a higher vapor concentration could be produced by passing a rapid flow of oxygen (in excess of 14 liters per minute) through the liquid Fluothane in the ether bottle. This vapor concentration could be further increased by having the vaporizer warmed and by having an adequate amount of Fluothane in the bottle. That is, the more fluid there was in the bottle the taller was the column of Fluothane through which the oxygen passes.

There was an age difference noted in the induction time. When the cases were grouped into three classes, one year old

and younger, one year old and older, and ponies, this difference can be seen. Thirteen horses one year old and younger, had an average induction time of 2.73 minutes. Thirty-one horses older than one year had an average induction time of 4.06 minutes, and the average induction time of six ponies was 3.92 minutes. The reason for this difference is undoubtedly due, in a large way, to the difference in size of the horses in the two age groups. No significance can be drawn from the induction time of the six ponies but it was thought best by the author to class them separately, rather than to include them in the two age groups.

The effect of preanesthetic tranquilizers on induction was also studied. Again the horses were placed into two age groups with the division between the groups being one year of age. In eight animals one year old and younger which received tranquilizers prior to anesthesia, the average induction time was 2.81 minutes. In five horses of the same age group which did not receive tranquilizers, the average induction time was 2.60 minutes. From this, one might assume that preanesthetic tranquilizers produce an increase in induction time, however, in the older age group, the opposite was found. In 17 horses of this age group which received tranquilizers the average induction time was 3.65 minutes. In five horses older than one year which were not premedicated with tranquilizers, the average was 4.40 minutes. This is what one would logically

expect. That is, it would be reasonable to assume that premedication with tranquilizing drugs would tend to shorten the induction time. The results obtained in the younger age group can not be overlooked, however.

The one definite advantage to using tranquilizers prior to induction was that the horses were much easier to handle while preparing them for induction. It was almost a necessity in those animals which were placed on the surgery table before induction to use tranquilization.

The method of induction which was found to be the most satisfactory and came to be the most used, was the method using succinylcholine chloride as a casting agent. To say that succinylcholine chloride is used as an anesthetic inducing agent is actually incorrect. This drug does not produce anesthesia in any way. It merely acts to cause muscle paralysis which in turn causes the horse to fall down and allows the horse to be restrained while being anesthetized by Fluothane. Therefore, in those instances in which succinylcholine chloride was used in the induction process, anesthesia is actually being induced by Fluothane.

The dose of succinylcholine chloride used was five mg. per 100 pounds of body weight and was injected in the jugular vein. Within a few seconds the horse would go down and the anesthetic apparatus was connected to the horse. In instances in which temporary apnea was produced by the drug, the appara-

tus was not connected to the horse until spontaneous respirations began.

In those horses in which thiamylal sodium was used, an actual light stage of anesthesia was produced by this drug. The dose (two grams in 40 cc. of sterile water) was injected as rapidly as possible into the jugular vein. The animal would then sink to the ground and the same procedure which was used with succinylcholine chloride was then followed.

The anesthesia produced by the thiamylal sodium was generally just to the point of nystagmus of the eye with very little muscle relaxation.

The induction time was less for this method of induction than in the method using succinylcholine chloride. The average induction time of six horses in which induction was accomplished by using thiamylal sodium was 2.67 minutes. Sixteen horses receiving succinylcholine chloride in the induction process averaged 3.13 minutes induction time. Both groups received premedication with promazine hydrochloride tranquilizers.

No induction excitement which is sometimes attributed to barbituate anesthesia was noted in this study.

The fact that Fluothane is a potent anesthetic was demonstrated by its being used alone for induction in 17 animals in this study. Some of these were anesthetized while being restrained on the surgery table whereas in other cases,

anesthesia was induced while the horse was standing.

Inhalation of the Fluothane vapors by the horse did not appear to produce any irritation to the respiratory mucous membranes nor did the odor of the fumes appear to be offensive to them. In no instance did the horse exhibit any reluctance to inhaling these fumes.

When anesthesia was induced in the standing animal using this method an ample supply of manpower was needed to steady the horse. It was not that the horse objected to inhaling the anesthetic gases, but rather when the horse became unsteady on his feet, it was sometimes rather difficult to keep him from moving away from the anesthetic machine. The horse would often object more to the restraint than to the anesthetic.

The average induction time in horses in which induction was completed with Fluothane alone was longer than in those horses in which either thiamylal sodium or succinylcholine chloride was used. Thirteen horses in this group averaged 4.1 minutes for induction of anesthesia to be completed. The groups receiving thiamylal sodium or succinylcholine chloride averaged 2.67 minutes and 3.13 minutes respectively.

In no instance was induction of anesthesia accompanied by an excitement stage or serious complications. In three cases there was some breath holding during induction which will be discussed later. The nearest thing to an excitement stage observed was an occasional extension of the limbs seen

in three horses. In these cases the horse would extend the legs and hold them rigid early in the induction process. As the level of anesthesia deepened the limbs would gradually relax and they could soon be easily flexed and manipulated. This phenomena may be similar to the transient period of generalized muscle rigidity reported by Chang et al. (6) during Fluothane induction of human patients.

In one horse a short period of running movements with the front legs was apparent. This was a mature horse which was premedicated with 250 mg. of Sparine and cast with 40 mg. of succinylcholine chloride. These running movements lasted approximately 30 seconds.

The fact that induction is accomplished rapidly and that there is no excitement stage associated with induction are important advantages to this type of anesthesia.

The per cent concentration of Fluothane used for induction was eight to ten per cent in five horses in which the Fluotec vaporizer was used.

Signs of Anesthesia

This was the author's first experience with inhalation anesthesia in the horse, and it is a technique not previously practiced at the Stange Memorial Clinic, therefore the signs of anesthesia for this type of anesthetic had to be learned

as the project progressed.

There was no one sign of anesthesia which could accurately indicate the stage of anesthesia found in this study, nor were there any groups of signs of anesthesia which would be correct for every horse anesthetized with Fluothane. The method of determining the stage of anesthesia was as follows. While the horse was receiving the initial Fluothane vapors the eye was watched closely for nystagmus and for the degree of reaction of the corneal and palpebral reflexes. When nystagmus began, the anus was checked to determine the degree of anal sphincter relaxation and to observe the degree of response the sphincter would make to palpation. The tail and limbs were manipulated to determine the amount of muscle relaxation present. When it was seen that the eye had passed through nystagmus, the anal sphincter was relaxed, the anal, corneal, and palpabral reflexes were weak or absent, and the limbs could be easily flexed, it was assumed the horse was in or near a plane of surgical anesthesia, and the vaporizer was turned off. Also, at this time, the respiratory rate was taken and recorded. The animal was observed for two or three minutes and if nystagmus began to return, or the horse made a movement, or if for any reason the plane of anesthesia was thought to be light, more Fluothane vapor was admitted to the system.

Once it was established that a surgical plane of anes-

thesia was reached, the most important sign of anesthesia then was the respiratory rate. At surgical anesthesia the respiratory rate will remain fairly constant and if the plane of anesthesia is deepened the rate will usually decrease, whereas if the plane becomes lighter, the respiratory rate will increase. Therefore, by watching the respiratory rate, one is able to maintain a fairly constant level of surgical anesthesia. The other signs of anesthesia must be observed also and used to evaluate the plane of anesthesia, but it appears that the rate of respirations is the most constant and reliable guide to surgical anesthesia when using Fluothane.

All the signs of anesthesia mentioned above were not present in each individual animal. Nystagmus and anal relaxation were often present, but not in all cases. The degree of reaction to corneal and palpebral stimulation varied considerably. A composite of all signs was necessary to indicate the degree of anesthesia.

Maintenance

The oxygen flow during maintenance of anesthesia was usually kept at two liters per minute. Although a theoretically closed system was used it was necessary to add oxygen at this rate to keep the rebreathing bag properly inflated. There were certain unavoidable leaks at various fittings and

connections within the anesthetic apparatus which would permit a constant loss of gases from the system. In one respect, this slight leakage is beneficial. That is, by constantly adding pure oxygen into the system, it dilutes the anesthetic vapors and makes it virtually impossible to get an increase in concentration of the anesthetic gas which could lead to overdose. On the other hand, this constant dilution of the vapors requires that new Fluothane fumes be periodically vaporized into the system to maintain an even plane of surgical anesthesia. This in turn requires that more Fluothane be used than if there were no leaks in the system.

During maintenance of anesthesia, the rebreathing bag was kept at a level which would not interfere with normal respirations in any way. If the bag was too full it would cause a resistance to expiration which may lead to an anesthetic build up in the lungs of the horse. If the rebreathing bag were allowed to become too empty, there would not be sufficient air for the horse to inhale and the horse would become anoxic. The volume of gases in the rebreathing bag was regulated by increasing or decreasing the flow of oxygen into the system.

When the signs indicated that the plane of anesthesia was becoming light (increased respiratory rate, return of nystagmus, increased anal reflex) more Fluothane vapor was admitted to the system by opening the vaporizer valve to the full on position and allowing it to remain open for 30 to 60 seconds.

Rarely was it necessary to leave this valve open for any longer period of time.

Early in the study, before the author was familiar with the signs of Fluothane anesthesia in the horse, the plane of anesthesia would occasionally become light enough to allow the horse to make a movement. These movements were never of a violent nature. In these cases the vaporizer valve would be left open for as long as a minute and a half. As proficiency in the technique was increased, the stage of anesthesia could be determined accurately enough so these movements were no longer allowed to occur.

It was necessary to keep the fluid level of the vaporizer at an adequate level to insure vaporization of the Fluothane. In this study 100 to 125 cc. of Fluothane was placed in the vaporizer bottle prior to anesthesia. The level was not allowed to become less than approximately 60 to 70 cc. during the anesthetic period. If the level of Fluothane did become less than this amount it was difficult to produce an adequate vapor concentration for anesthesia due to the short column of fluid through which the oxygen was passed.

Fluothane in bottles which had been opened for some time or which had been used in several (four or five) anesthetic periods appeared to lose some of its anesthetic potency. Because of the high cost of the drug the discarding of Fluothane which had been used in a few anesthesias was not economically

practical. Therefore, the practice of always combining some of the "used" Fluothane with some from a newly or recently opened bottle was used. For routine procedures, a total volume of 100 cc. usually proved adequate. Of this total, approximately 60 cc. would be the older liquid and 40 cc. would be the newer Fluothane. The advantage of this practice was that the potency of the fresh Fluothane was available while the older Fluothane furnished volume to provide for proper vaporization. In this way wasting of Fluothane was minimized. No adverse effects were observed using this combination which would indicate any concentration of toxic products.

No accurate records were kept on the length of time that the baralyme absorber could be used. It was routinely changed when some of the baralyme crystals in the top portion of the cylinder became blue in color. Not all the crystals were blue in color; many were a faded pink color. It was noted that there were very few blue crystals beneath the top layer of crystals. Deeper in the absorber most of the crystals were still pink in color. It was felt, however, that a difference in efficiency of carbon dioxide absorption could be detected when the top layer of crystals began to assume a faded pink color. This difference was associated with an increase in the respiratory rate of the anesthetized horse.

Cardiovascular Effects of Fluothane Anesthesia

The pulse rate in the horses anesthetized in this study was found to average about 36 to 44 for racing horses, 48 to 56 for nonracing animals over one year of age, and 54 to 60 in nonracing animals one year old and younger.

During induction and early in maintenance these pulse rates were usually increased.

In one case the pulse rate became accelerated when the rebreathing bag was allowed to become deflated and the horse became hypoventilated.

In another instance the heart rate became quite irregular during maintenance of anesthesia. This condition was greatly improved by flushing the anesthetic system with pure oxygen and allowing the horse to breath pure oxygen for five minutes.

A third heart sound was observed in two anesthetized horses. These third sounds were not noted in the preanesthetic examination of these animals. In one of these cases this extra sound was noted on the first day postoperative but could not be detected on the second day postoperative.

Electrocardiogram irregularities during Fluothane anesthesia were not observed during the anesthetic periods in which electrocardiograms were made. In three of the tracings an occasional extra systole (Fig. 19 and 20) was noted prior to anesthesia and during induction. These extra systoles were

no longer seen after the horse was in a plane of surgical anesthesia except in one case in which the extra systoles persisted during the first 30 minutes of anesthesia. They were no longer noted after this time during the remainder of the anesthetic period. In two of the tracings the rhythm of the heart was shown to be somewhat irregular prior to and during the early stages of anesthesia. Shortly after surgical anesthesia was reached, the rhythm became regular. After about 50 minutes of anesthesia the rhythm began to become a little irregular again. These two tracings were made in the same horse during different anesthetic periods.

The electrocardiogram tracings show that the heart rate is accelerated early in the induction process, but as induction is completed the rate slows and becomes quite regular during maintenance.

Even in the only fatality of this study, the electrocardiogram remained quite regular during the respiratory arrest before death.

It was found that Fluothane anesthesia causes a decrease in the arterial blood pressure of the horse. The greatest amount of hypotension was seen at the end of the induction period. In the horses studied there was an average fall of 50 mm. Hg during this period. The pressure fell from an average preinduction pressure of 106 mm. Hg (range, 50 to 62 mm. Hg). After induction the arterial blood pressure rose slowly

during maintenance. The amount it raised depended on the anesthetic concentration.

The response of venous blood pressure to Fluothane anesthesia did not appear to be very great in this study. In two instances it was decreased slightly during anesthesia and in one instance it remained nearly the same.

Because of the limited number of anesthetized horses (four) in which blood pressure studies were conducted it was decided to discuss each one individually and to present a graph depicting the blood pressure changes which took place (Figs. 21, 22, 23, 24).

From the results obtained from the hemogram studies of six horses, it appears that Fluothane does not produce any significant changes in the number of blood cells in the circulating blood during anesthesia. The results of these studies are presented in Table 4.

In a limited study on the effects of Fluothane anesthesia on blood gases it was found that there was an overall increase in both arterial and venous blood oxygen during anesthesia in all three cases. The results on carbon dioxide levels were not consistent. In one horse both arterial and venous carbon dioxide levels were increased and in one horse both levels were decreased. A third horse had an arterial carbon dioxide level which remained nearly the same while the venous level increased slightly (Table 5).

Effect of Fluothane on Respiration

Fluothane anesthesia generally causes a decrease in respiratory rate in the horse. In this study the respiratory rate was decreased in 24 horses, increased in eight horses and remained at the same level in five horses. The tendency toward a decrease in respiration was seen more in horses older than one year than in horses one year old and less. In the older age group 19 increased, three decreased, and four remained the same. In the younger horses five increased, five decreased, and two remained the same.

The average respiratory rate during Fluothane anesthesia appears to vary according to age and the purpose for which the horse is used. In racing animals the rate was from six to ten per minute during surgical anesthesia, while in nonracing animals the average rate was from 12 to 16 per minute. In horses less than one year old the average was from 16 to 22 per minute. All horses in this lower age group were of the nonracing type.

Breath holding was observed in three horses. The first time this was noted, it was attributed to pain stimuli due to the surgery in an inadequately anesthetized horse. The second time this occurred it was during induction and the cause was not known. On the third occasion, also during induction, it was thought that perhaps it was a reflex act in a light plane

of anesthesia. Therefore, the plane of anesthesia was deepened and respiration became much more regular, although breath holding did occur spasmodically during maintenance. This same horse was anesthetized three times with the occurrence of breath holding each time. In these instances of breath holding, the pattern was quite regular. Respirations would cease for 30 or 40 seconds and then the horse would respire normally a few seconds and then hold his breath again for another 30 or 40 seconds. Tracings of this can be seen in the illustrations (Fig. 25).

Respiratory arrest was produced during anesthesia in one animal. In this case the original anesthetic period was over and the horse was in the early recovery period when it was decided to take some radiographs of this horse necessitating anesthesia again. Induction was begun again in the usual manner. Within three minutes respirations grew progressively weaker and ceased. The animal was disconnected from the anesthetic machine and artificial respiration began. The horse responded immediately and was breathing spontaneously within two minutes. It is felt that the concentration used in induction of this partially anesthetized horse was too great and produced the respiratory arrest.

In another instance respirations became very slow and shallow soon after induction. The anesthetic system was flushed with oxygen and the horse was allowed to breathe pure

oxygen. Within five minutes the horse was breathing normally again.

By these two cases just mentioned it can be seen that respirations respond very rapidly to changes in concentration of Fluothane. This response is well illustrated by the anesthesia record of a four year old Thoroughbred gelding shown in the illustrations (Table 6).

An interesting occurrence noted in one of the respiratory tracings was the appearance of two different respiratory rates, one following the other in a regular pattern. One of the rates was 24 per minute and the other was 12 per minute (Fig. 26).

Only one known horse suffering from severe chronic pulmonary alveolar emphasema (heaves) was anesthetized with Fluothane. This horse exhibited very labored respirations and a very persistent cough prior to anesthesia. It was obvious that the condition was of long standing duration.

Under anesthesia a definite improvement in respiration was noted. Respiratory movements were much easier and the horse ceased to cough. Perhaps this could be similar to the beneficial response seen in human asthmatics under Fluothane anesthesia.

Muscle Relaxation

Fluothane anesthesia produced adequate muscle relaxation for all of the surgical procedures performed in this study. It gave good relaxation for the orthopedic surgery and for the repair of luxated joints. In the splenectomies done under Fluothane anesthesia there was good relaxation of the abdominal musculature. The same was true for the umbilical hernias and crypt orchid castrations.

This muscle relaxing property of Fluothane was quite beneficial in the one dystocia of the study. This was a pony mare which had been in labor for seven hours prior to anesthesia. Fluothane anesthesia caused a cessation of straining and uterine contractions so that an embryotomy of a hydocephalis foal could be performed with relative ease.

Other Clinical Observations

Excessive secretions in these horses under Fluothane anesthesia were not observed in this study. The only fluids noted in the face mask at the end of the operation were from condensation of the respiratory vapors.

An occasional horse would perspire rather profusely during anesthesia. Generally, this was noted early in the anesthetic period and could be associated with casting and pre-

induction struggling. In one instance, the sweating was believed to be due to painful stimulation in an inadequately anesthetized animal. There were, however, two horses in which this profuse sweating could not be accounted for by mere observation alone.

No cases were eliminated from this study because of illness or poor physical condition, and in no instances was there any evidence of anesthetic shock.

The effect of Fluothane on the amount of hemorrage at the surgical sight was observed and it did not appear clinically to increase or decrease in any appreciable amount.

In those horses which were anesthetized more than one time, no adverse effects due to the Fluothane were observed clinically. In the two horses that were anesthetized three times and in one which was anesthetized twice, there was no evidence of cardiac disfunction that could be observed electrocardiographically. None of the horses, under Fluothane anesthesia for more than one time, went off feed or exhibited any signs of clinical illness. One pregnant mare was anesthetized twice with no ill effects.

This project did not include a study of the effects of Fluothane on pregnant mares. There was however, one known pregnant mare which was anesthetized on two different occasions that later gave birth to a live, healthy foal. This mare was anesthetized in the fourth and seventh month of

pregnancy. In both instances, the mare received premedication with promazine hydrochloride and induction by succinylcholine chloride.

Amount Used

The amount of Fluothane used for anesthesia was also studied in this project. When calculated as the amount used per hour of anesthesia it was noted that as the length of anesthetic period became greater the amount of Fluothane used per hour became less (Table 7). On this basis, those periods of less than 30 minutes of anesthesia required the greatest amount of anesthesia in that it required 62.4 cc. of Fluothane per hour. Results of the other time groups were as follows. Procedures of 30 to 60 minutes duration required 34.2 cc. per hour, procedures of 60 to 90 minutes used 30.5 cc. per hour, and procedures of 120 to 150 minutes used an average of 28.3 cc. per hour. One case of 165 minutes duration used 27.1 cc. per hour, and in another case lasting 193 minutes, 28.3 cc. per hour was used. Because the greatest amount per hour was used in the shortest procedures, it can be seen that the largest amount of Fluothane was used for induction. Thereafter only slight amounts are needed for maintenance of anesthesia.

Horses which received preanesthetic tranquilizers used

less Fluothane on the average than did the horses which were not tranquilized. In horses anesthetized for 30 to 60 minutes 11 pretranquilized horses required an average of 32.7 cc. per hour, while six horses not receiving tranquilizers required 36.7 cc. per hour. In a group anesthetized for 60 to 120 minutes, 11 which were premedicated needed 28.2 cc. per hour, and the four which received no premedication used 37.5 cc. per hour.

Recovery

The time required for recovery from anesthesia was recorded for most cases. It is considered as the time elapsing from when the animal was disconnected from the anesthetic machine until the horse would stand. In the 47 horses in which recovery time was recorded the average time was 29.3 minutes with the range being from eight minutes to 92 minutes.

The length of recovery time appears to increase with an increase in duration of the anesthetic period. In 19 horses anesthetized from 30 to 60 minutes the average recovery time was 23.3 minutes. In 12 horses under Fluothane anesthesia for 60 to 90 minutes the recovery time was 29.4 minutes. While in 11 horses anesthetized for longer than 90 minutes the average recovery time was 38.0 minutes.

Another factor influencing the recovery time was the

preanesthetic administration of tranquilizing drugs. From this study it would appear that they increase recovery time by about ten minutes. In horses anesthetized for 30 to 60 minutes, the 12 animals receiving preanesthetic tranquilizers had a recovery time of 28.1 minutes, whereas six animals which did not receive tranquilizers had an average recovery time of 18.0 minutes. A similar trend is seen in horses anesthetized for 60 to 120 minutes. Fifteen were premedicated with tranquilizers and three were not. Those which were tranquilized recovered in 34.8 minutes, while those not tranquilized recovered in 23.3 minutes.

When the anesthetic system was flushed with pure oxygen, and the horse was allowed to breathe pure oxygen for five to ten minutes, no difference in the recovery time was seen.

Of the three areas in which recovery took place, a turf area, a box stall, and on rubber mats in the surgery room, the most suitable was found to be the darkened, well bedded stall. The stall was free from external stimulation and the horse was allowed to regain consciousness and stand at his own will. When horses recovered on the rubber mats or on the turf area, nearby activity would often cause the horse to attempt to rise before he was fully conscious. Therefore, these horses had to be attended until they were awake and ready to stand.

No struggling was observed during recovery. The horse would generally roll to its sternum and remain in this posi-

tion for a few minutes and then rise to its feet. In an occasional racing horse the animal would attempt to stand very soon after anesthesia and would have to be restrained from doing so until he was able to stand. If these horses were not prevented from trying to rise on their first and second attempts, they would usually fall back down.

No postoperative complications were noted following Fluothane anesthesia. The horse would usually be eating and apparently feeling well the day following surgery. There did not appear to be any postanesthetic depression associated with Fluothane. They were much brighter postoperatively than two horses which were anesthetized with chloroform using this same apparatus.

In those few instances in which the anesthesiologist and surgeon were one in the same person, it was possible to successfully direct the anesthesia and perform the surgery at the same time. After induction and during surgery the surgeon would have to periodically give instructions to an assistant who would manipulate the controls of the anesthetic machine according to instructions. It is felt that with some practice a person could become accustomed to observing the anesthetic machine and the signs of anesthesia while doing surgery to the point that a satisfactory plane of anesthesia could be maintained.

It is further felt that the Fluotec vaporizer, which can

deliver a constant percentage of Fluothane concentration would lend itself well to such a technique.

Fluotec Vaporizer

The Fluotec vaporizer performed well in five cases in which it was used. Induction was a little slower with this vaporizer than with the ether vaporizer, probably because a higher concentration of Fluothane vapors could be produced by running both the oxygen flow and ether vaporizer at full capacity.

Once induction was completed, the Fluotec unit required much less attention during maintenance. The desired concentration could be set on the Fluotec control whereas periodic vaporizations were necessary with the ether bottle as the plane became light.

The Fluotec vaporizer could therefore maintain the plane of anesthesia at a more constant level.

Fatality

There was one fatality during anesthesia in the project. The horse was a 12 year old, 775 pound, experimental gelding. This animal was suffering from a rather severe case of laminitis and was not in the best physical condition. The proce-

dure being performed was the insertion of permanent polyvinyl catheters into the carotid artery and jugular vein. The horse received 300 mg. of Sparine tranquilizer about 60 minutes prior to induction. Induction was as follows. The horse was led into the surgery room and stood beside a large animal surgery table which was in the vertical position. The horse was then secured to the table by ropes around the legs, thorax, and abdomen. The table was rotated to the horizontal position. Much struggling occurred at this time. More struggling of the horse occurred while the surgical sight was being prepared and the electrocardiogram electrodes were being attached to the limbs. At 1:37 induction with Fluothane was begun. Five minutes later (1:42) induction was considered complete. The palpebral reflex was gone and the tail was limp. The anal reflex was strong and the corneal reflex was fair. Nystagmus had never been observed. At 1:45 the respiratory rate was 22 and the pulse rate was 60 per minute. At 1:50 the respiratory rate was 26 and the pulse was 62. The horse did not appear to be in a very deep plane of anesthesia and more Fluothane vapors were admitted to the system for one minute. At the end of this minute of vaporization, the eye was in nystagmus, but the anal reflex was still strong. At 1:55 respirations suddenly ceased. The signs of anesthesia had just been checked and it was determined that the plane of anesthesia was light. The author was about to add more Fluo-

thane vapors to the system. The anesthesia machine was immediately removed from the horse and artificial respiration was begun with no results. The pulse rate at 2:00 was 70 per minute. The anesthetic system was flushed with oxygen and connected to the horse again and attempts were made to resuscitate the horse by forcing respirations with the rebreathing bag, but again there was no response. In a final attempt to stimulate respirations, a tracheal catheter was passed and efforts were made to inflate the lungs. All efforts failed and the horse was pronounced dead at 2:08.

The electrocardiogram showed the heart to remain quite regular until it stopped.

Later examination of the anesthetic machine revealed that the inhalation and exhalation tubes were reversed. In one of the euthanasia studies these tubes were purposely reversed during anesthesia for 30 minutes. No detrimental effects were noted in this instance.

Post-mortem examination of this horse did not reveal any gross pathologic lesions. The right side of the heart may have been slightly dilated and the left side was in rigid contraction. A few Gastrophilus sp. larva were found in the stomach.

Death was attributed to respiratory collapse.

Euthanasia Studies

Case 1

This was an eight month old filly weighing approximately 325 pounds, which was destroyed because of malformed legs.

This horse received no premedication and induction was completed using Fluothane alone.

Seven minutes following induction, the oxygen flow was increased to 14 liters per minute and the vaporizer valve was turned to full capacity for a few minutes. Both valves were turned off and the animal was allowed to breathe this mixture. This process was repeated until the horse died. During the last five minutes of the euthanasia process, the pony took only four or five shallow breaths but the heart remained fairly regular throughout this time period. The total amount used was 54 cc. of Fluothane.

Case 2

This animal was a two year old Shetland pony. No premedication was given and the induction process included 35 mg. of succinylcholine chloride.

After induction, the pony was maintained at a plane of surgical anesthesia for 15 minutes. Then the inhalation and exhalation tubes were reversed, so that the inhalation tube now was connected to the absorber canister. This was done to observe the effect such a change would have on the animal.

In the fatality of this study, the tubes were inadvertently reversed such as they were in this euthanasia study, and there was some speculation that this may have been a contributing factor to the death of the horse. However, in this pony, anesthesia was maintained with the inhalation and exhalation tubes reversed with no obvious effect on the animal.

The tubes were then put back to the normal position and the oxygen flow meter set on 14 liters and the vaporizer valve on full open. After running ten to 15 minutes of vaporization in this manner, respirations were shallow and slow, but it did not appear that it was going to cause death. The fluid level in the vaporizer bottle was getting rather low so both the oxygen and the vaporizer were shut off and the author left the room to get more Fluothane. Upon return, in less than three minutes, the pony was found dead.

This illustrates an important point. Even though there are no more anesthetic vapors being added to the system, there may be a sufficient concentration of anesthetic already present which may cause death when there is not a constant supply of oxygen added.

Case 3

Euthanasia was unsuccessful in the third horse. This 1000 pound, four year old also received no premedication and was given succinylcholine chloride.

The horse was maintained at a level of surgical anesthe-

sia for two hours and 14 minutes. Then the attempted euthanasia was began by increasing the anesthetic concentration. In about ten minutes the respirations were weak and down to three per minute, but the vaporizer bottle became empty and within 11 minutes the respirations were back to a normal rate. More Fluothane was added and the euthanasia process was started again. Respirations were again slowed, but they could not be completely stopped. After 20 minutes of vaporization without success it was decided to discontinue the attempted euthanasia.

It was interesting to note that when electrical euthanasia was tried it also met with some problems. This horse received two, five second periods of 110 volts and survived. The third period of 20 seconds of 110 volts did produce death.

SUMMARY AND CONCLUSIONS

Fluothane proved to be a good general anesthetic in the horse when used according to the technique described in this study.

Induction of anesthesia did not present any particular problems in any of the methods used. The method which was found to be the most convenient to use was the method in which succinylcholine chloride was employed as a casting agent and anesthesia was induced with Fluothane. When thiamylal sodium was used for induction, it produced a light plane of anesthesia which brought about a decrease in induction time. Fluothane proved to be sufficiently potent to induce anesthesia without the aid of other drugs.

Both the method of incorporating thiamylal sodium in the induction process and the method of using Fluothane alone were satisfactory methods of inducing anesthesia.

The average induction time of all cases studied was 4.09 minutes. Induction time was much shorter in horses in which the ether bottle vaporizer was used then in those in which the Fluotec vaporizer was used. The method of induction which gave the shortest induction time was induction by thiamylal sodium which had an average time of 2.67 minutes. The method using succinylcholine chloride in the induction process had an average of 3.13 minutes. The average time when induction

was by Fluothane alone was 4.10 minutes. There was a difference in induction time seen in horses less than one year of age and horses older than one year. Induction time in the older horses averaged 4.06 minutes and was 2.73 minutes in the younger horses. This difference is felt to be largely due to the difference in the size of the animals in the two groups.

Preanesthetic tranquilization gave varying results in the induction time. It produced a slight increase in induction time of horses one year old or younger, and a decrease in the induction time of horses older than one year. The fact that tranquilized horses were easier to handle during induction was an advantage of preanesthetic tranquilization.

Excitement was negligible during induction of anesthesia. Three horses exhibited extension of the limbs and one had slight running movements during early induction. These conditions were of very short duration and ceased as the plane of anesthesia became deeper.

The signs of anesthesia used to indicate the stage of anesthesia in this study were nystagmus, corneal and palpebral reflexes, degree of anal sphincter relaxation, anal reflex, respiratory rate, and relaxation of the tail and limbs.

Once a maintenance plane of anesthesia was reached, the most important sign of anesthesia was found to be the respiratory rate. The respiratory rate would usually increase as the

plane of anesthesia became lighter, and would decrease when the plane deepened.

Not all the signs of anesthesia mentioned were present in all the animals studied, and no one sign was found to accurately indicate the anesthetic plane in all cases. A composite of all signs was found necessary to determine the plane of anesthesia.

Maintenance of anesthesia was achieved by allowing the horse to rebreathe the anesthetic vapors present in the system from induction. New anesthetic fumes were periodically vaporized into the system when the signs of anesthesia indicated a higher concentration was necessary to keep the horse at a plane of surgical anesthesia. When the Fluotec vaporizer was used the controls were set on a percentage that maintained a good level of anesthesia and remained at that setting throughout the anesthetic period.

Oxygen was usually added to the system at a rate of two liters per minute. This rate was necessary to keep the volume of air in the rebreathing bag at an adequate level. Certain unavoidable leaks were present in the system, which necessitated the constant addition of oxygen. This constant addition of oxygen in turn required periodic vaporizations to keep the Fluothane concentration high enough to maintain surgical anesthesia. This dilution of the anesthetic vapors was thought to be beneficial in that it prevented any occurrence of an

unwanted anesthetic build up but did require that more Fluothane be used than if there was no such dilution.

The rebreathing bag was kept at a level of inflation which did not interfere with respiration.

The carbon dioxide absorber was changed when the normal pink color of the top layers of crystals turned to a blue color.

The pulse rate of racing horses anesthetized with Fluothane was observed to be from 36 to 44 per minute. In nonracing horses older than one year this rate averaged 48 to 56 per minute, and 54 to 60 in nonracing horses younger than one year.

In nearly all instances the pulse rate was accelerated during induction and early maintenance.

The pulse became quite irregular in one horse during anesthesia. This irregularity was rapidly improved by flushing the anesthetic system with oxygen and allowing the horse to breathe pure oxygen for a few minutes.

Third heart sounds were observed in two anesthetized horses.

Electrocardiograms of nine horses under Fluothane anesthesia showed no irregularities. In three cases an occasional extrasystole was noted. These extrasystoles were not thought to be significant by the author. When they were noted, it was during preinduction and early in anesthesia. As the plane of

anesthesia was increased they were no longer seen.

In one horse which was anesthetized twice, the electrocardiogram showed the pulse rate to be somewhat irregular during induction and early maintenance. During maintenance the rate became regular about 50 minutes after which it began to be a little irregular again.

Fluothane causes a decrease in arterial blood pressure in the horses in which blood pressure was studied. The greatest hypotension was seen at the end of induction. After this time the blood pressure gradually increased toward a normal level.

There was little change observed in the venous pressure in the anesthetized horse.

Blood cell numbers were not significantly altered by Fluothane anesthesia.

Both arterial and venous oxygen levels were increased in three horses in which blood gas determinations were run. However, the blood levels of carbon dioxide were not found to be consistent. Because the study of the phase of Fluothane anesthesia was so limited it is difficult to make any conclusions on these findings.

The respiratory rate was found to respond rapidly to changes in Fluothane concentration. This rate was generally decreased during surgical anesthesia. There was, however, a tendency for the rate to be increased in younger subjects

during anesthesia. The average rate of the anesthetized racing horse was six to ten per minute. Respiratory rates for nonracing horses were higher. In nonracing horses older than one year it was from 12 to 16 per minute, and in those animals less than one year old the rates were from 16 to 22 per minute.

Breath holding was noted in three horses. In one instance it was associated with pain due to an inadequate level of anesthesia. In the other two it was thought to be due to a reflex act in light stages of anesthesia. The breath holding in these cases was pretty well controlled by increasing the depth of anesthesia.

One case of respiratory arrest was seen excluding the fatality of this series. It was corrected by disconnecting the horse from the anesthetic apparatus and applying artificial respiration. In another case the respirations became very slow and weak. Improvement in the rate and character of respirations was noted after giving the horse two minutes of pure oxygen.

Respirations were noted to be improved during Fluothane anesthesia in a horse suffering from severe chronic pulmonary alveolar emphasema.

The muscle relaxing property of Fluothane was found to be quite good. The muscle relaxation in Fluothane anesthetized horses was satisfactory for all surgical procedures attempted in the project.

There was no evidence of excess respiratory or gastric secretions observed in this study nor was there any anesthetic shock. There were two horses in which profuse perspiring could not be accounted for.

Hemorrhage at the surgical sight was not noted to increase or decrease under the effects of Fluothane.

One pregnant mare was anesthetized twice in this study. This mare later gave birth to a live and normal foal.

The area which proved to be the most satisfactory for recovery was a quiet, well bedded, box stall which was as free from external stimuli as possible.

The average recovery time from Fluothane anesthesia was 29.3 minutes with a range of from eight minutes to 92 minutes. An increase in recovery time was associated with an increase in the duration of the anesthetic period. Preanesthetic tranquilizers also were found to increase the time of recovery.

No beneficial decrease in recovery time was observed when the anesthetic system was flushed with pure oxygen and the horse allowed to breath pure oxygen for five or ten minutes at the end of the surgical procedure.

In those cases in which the surgeon and the anesthesiologist were the same person satisfactory results were obtained. From this it is felt that one man can develop a technique in which he can direct the anesthesia and perform the surgery at the same time. The Fluotec vaporizer worked well in these

cases.

The controlled percentage Fluotec vaporizer performed well when it was used. Induction was slower with the vaporizer but maintenance of anesthesia was much easier. The vaporizer control could be set at the desired level and left there during the procedure. It is the belief of this author that the Fluotec vaporizer shows much promise to becoming a valuable asset in this type of anesthesia.

There was one fatality in this study. This was a 12 year old gelding anesthetized for the placement of permanent catheters in the carotid and jugular vessels. Although the signs of anesthesia indicated the horse to be in a light plane of anesthesia, respirations suddenly ceased 21 minutes after induction. All efforts to revive the horse failed. Post-mortem examination failed to reveal any gross pathological lesions. Death was attributed to respiratory collapse.

Two horses were euthanized by overdosing with Fluothane. Death was also due to respiratory collapse. The heart remained relatively normal for five to six minutes after respirations had stopped. In another horse in which euthanasia was attempted by this same method, death could not be produced by Fluothane in this anesthetic apparatus.

From these studies it is the belief of this author that Fluothane is a potent drug capable of producing safe and practical general anesthesia in the horse.

TABLES AND ILLUSTRATIONS

Table 1. Case studies

No.	Wt. #	Breed	Age	Sex	Clin.	Exp.	Premed.	Induction	Induction time (min.)	Anes. period (min.)	Amount used (cc.)	Recovery (min.)
1	450	Grade	4 mo.	M		x	150 mg. Sparine	25 mg. Sucostrin	--	--	--	--
2	450	Am. saddle	6 mo.	S	x		150 mg. Sparine	Fluothane	4 1/2	85	35	--
3	700	Palamino	1 yr.	S	x		250 mg. Sparine	35 mg. Sucostrin	1	24	15	28
4	--	Standardbred	8 yr.	M	x		250 mg. Sparine	2 g. Surital	5	32	--	27
5	1000	Throughbred	6 yr.	M	x		250 mg. Sparine	2 g. Surital	9	60	--	--
6	975	Throughbred	5 yr.	G	x		300 mg. Sparine	2 g. Surital	2	--	26	18
7	800	Grade	9 yr.	M		x	250 mg. Sparine	40 mg. Sucostrin	--	90	25	25
8	1015	Throughbred	7 yr.	G	x		250 mg. Sparine	2 g. Surital	3 1/2	59	34	35
9	1000	Throughbred	4 yr.	S	x		350 mg. Sparine	2 g. Surital	1 1/2	82	30	37
10	400	1/4	5 mo.	M	x		125 mg. Sparine	Fluothane	3 1/2	35	22	38
11	1100	Throughbred	4 yr.	G	x		350 mg. Sparine	2 g. Surital	1 1/2	68	--	32
12	300	1/4	5 mo.	S	x		100 mg. Sparine	Fluothane	1 1/2	31	12	16
13	1150	Throughbred	4 yr.	G	x		300 mg. Sparine	3 g. Surital	2 1/2	98	46	92
14	950	Throughbred	3 yr.	M	x		None	40 mg. Sucostrin	3	51	32	24

Table 1. (Continued)

No.	Wt. #	Breed	Age	Sex	Clin.	Exp.	Premed.	Induction	Induction time (min.)	Anes. period (min.)	Amount used (cc.)	Recovery (min.)
15	950	Throughbred	4 yr.	S	x		None	40 mg. Sucostrin	3	92	46	14
17	700	Standardbred	1 yr.	S	x		200 mg. Sparine	Fluothane	3 1/2	52	15	35
18	950	Throughbred	6 yr.	M	x		250 mg. Sparine	45 mg. Sucostrin	4	61	43	10
19	550	Belgian	6 mo.	S	x		None	Fluothane	2	71	36	31
20	750	Grade	--	S		x	300 mg. Sparine	Fluothane	3 1/2	138	64	24
21	475	Appaloosa	10 mo.	S	x		None	Fluothane	2 1/2	48	29	8
22	1050	1/4	6 yr.	G	x		None	40 mg. Sucostrin	3 1/2	79	61	25
23	800	Grade	4 yr.	M		x	400 mg. Sparine	Fluothane	3	117	57	40
24	775	Grade	12 yr.	G		x	300 mg. Sparine	Fluothane	5	--	--	--
25	1100	1/4	4 yr.	S	x		250 mg. Sparine	Fluothane	6	8	31	17
26	650	Shetland	3 yr.	S	x		150 mg. Sparine	Fluothane	5	27	18	28
27	900	Am. saddle	5 yr.	M	x		250 mg. Sparine	40 mg. Sucostrin	3	24	36	15
28	800	Arabian	4 yr.	M	x		150 mg. Sparine	40 mg. Sucostrin	3	50	20	15
29	700	Palamino (1/4)	2 yr.	M	x		250 mg. Sparine	35 mg. Sucostrin	2	16	22	75

Table 1. (Continued)

No.	Wt. #	Breed	Age	Sex	Clin.	Exp.	Premed.	Induction	Induction time (min.)	Anes. period (min.)	Amount used (cc.)	Recovery (min.)
30	350	Grade	5 mo.	S	x		None	20 mg. Sucostrin	2 1/2	51	32	25
31	500	Grade	1 yr.	S		x	250 mg. Sparine	Fluothane	3 1/2	138	57	23
33	800	1/4	1 yr.	S	x		200 mg. Sparine	40 mg. Sucostrin	5 1/2	49	41	18
34	800	Grade	4 yr.	M		x	400 mg. Sparine	Fluothane	6	193	91	45
35	500	Grade	1 yr.	S		x	200 mg. Sparine	Fluothane	6 1/2[a]	93	62	37
36	450	Shetland	1 yr.	S		x	200 mg. Sparine	Fluothane	7[a]	96	47	42
37	625	1/4	1 yr.	M	x		200 mg. Sparine	30 mg. Sucostrin	2 1/2	54	14	27
38	500	Grade	1 yr.	S		x	150 mg. Sparine	30 mg. Sucostrin	14[a]	157	71	38
40	450	Shetland	4 yr.	M	x		150 mg. Sparine	Fluothane	4 1/2	60	20	45
41	450	Shetland	1 yr.	S		x	150 mg. Sparine	Fluothane	7 1/2[a]	124	67	41
42	825	1/4	12 yr.	S	x		None	40 mg. Sucostrin	7 1/2	60	43	--
43	1000	Throughbred	5 yr.	S	x		250 mg. Sparine	40 mg. Sucostrin	7	80	39	27
44	400	P. O. A.	2 yr.	M	x		125 mg. Sparine	Fluothane	3 1/2	47	26	20

[a]Fluotec vaporizer.

Table 1. (Continued)

No.	Wt. #	Breed	Age	Sex	Clin.	Exp.	Premed.	Induction	Induction time (min.)	Anes. period (min.)	Amount used (cc.)	Recovery (min.)
45	450	Shetland	8 yr.	G	x		150 mg. Sparine	25 mg. Sucostrin	3	62	30	18
46	900	1/4	--	M	x		250 mg. Sparine	--	--	--	--	--
47	1100	Throughbred	4 yr.	S	x		300 mg. Sparine	50 mg. Sucostrin	3	70	--	8
48	725	1/4	1 yr.	S	x		None	30 mg. Sucostrin	8	39	30	20
49	800	Grade	3 yr.	S	x		275 mg. Sparine	35 mg. Sucostrin	3	66	35	70
50	850	Grade	4 yr.	G	x		300 mg. Sparine	45 mg. Sucostrin	2 1/2	115	50	22
51	850	1/4	3 yr.	M	x		250 mg. Sparine	40 mg. Sucostrin	3	71	26	25
52	100	Grade	17 day	S		x	None	Fluothane	2	29	14	16
53	600	1/4	1 yr.	S	x		175 mg. Sparine	30 mg. Sucostrin	2 1/2	25	13	8
54	700	Appaloosa	2 yr.	S	x		250 mg. Sparine	30 mg. Sucostrin	3 1/2	57	37	59
55	800	1/4	12 yr.	S	x		300 mg. Sparine	Fluothane	6 1/2	39	31	8
56	900	Grade	8 yr.	M		x	None	2 g. Surital	3	35	25	14
57	800	1/4	2 yr.	S	x		250 mg. Sparine	40 mg. Sucostrin	3 1/2	34	29	30
58	--	1/4	1 yr.	M	x		None	Fluothane	4[a]	72	--	--

Table 2. Surgical procedures during Fluothane anesthesia

Removal of abnormal growths	8
Removal of joint chips	7
Umbilical hernia repair	6
Canulating carotid and jugular vessels	5
Splenectomy	4
Removal of fractured proximal seasmoid	3
Cryptorchid castration	3
Neurectomy	2
Cataract removal	2
Reduction of luxated joint	2
Removal of fractured small metatarsal	1
Resection of annular ligament	1
Simple castration	1
Embryotomy	1
Removal of cystic calculus	1
Others	2

Table 3. Induction

Tranquilizer + Succinylcholine + Fluothane	=	17
Tranquilizer + thiamlyl Na + Fluothane	=	7
Tranquilizer + Fluothane	=	19
Succinylcholine + Fluothane	=	8
Thiamlyl Na + Fluothane	=	1
Fluothane alone	=	4

Table 4. Hemogram results

	Pre or early anesthesia	Midway in anesthesia	Near end of anesthesia
Hemoglobin			
No. 7	9.96	9.58	9.22
No. 10	9.96	10.74	10.74
No. 14	15.37	16.82	15.81
No. 21	11.15	10.74	11.56
No. 53	10.74	12.37	
Erythrocytes			
No. 7	5,220,000	5,770,000	6,400,000
No. 10	8,300,000	9,820,000	10,230,000
No. 14	9,870,000	9,200,000	10,010,000
No. 15	11,590,000	11,030,000	9,880,000
No. 21	8,150,000	8,450,000	7,200,000
No. 53	7,890,000	8,670,000	
Leucocytes			
No. 7	9,450	9,950	9,850
No. 10	34,900	32,950	48,940
No. 14	14,100	9,050	11,750
No. 15	20,450	15,050	26,500
No. 21	10,300	10,750	10,350
No. 53	8,700	8,750	
Lymphocytes			
No. 7	4,000	4,200	2,500
No. 14	6,200	3,200	4,200
No. 21	4,300	3,500	3,300
No. 53	4,300	3,800	
Mature neutrophils			
No. 7	3,000	3,100	4,800
No. 14	3,400	2,800	3,900
No. 21	3,600	4,500	5,700
No. 53	3,300	200	
Immature neutrophils			
No. 7	1,800	2,400	1,000
No. 14	3,800	3,000	3,200
No. 21	2,200	2,600	1,300
No. 53	4,300	3,800	

Table 5. Blood gas determinations

	Arterial (vol. %)			Venous (vol. %)		
	CO_2	O_2	N_2	CO_2	O_2	N_2
Case 34						
48 min. of anes.	54.5	15.5	2.4	57.1	10.6	0.7
73 min. of anes.	51.9	16.9	1.9	54.2	14.5	1.0
111 min. of anes.	49.3	19.4	2.4	50.8	15.8	0.2
134 min. of anes.	51.1	17.1	0.5	50.3	16.4	1.2
Case 38						
Preinduction	48.5	10.7	--	51.1	7.7	--
47 min. of anes.	49.5	12.8	--	49.3	12.1	--
97 min. of anes.	48.8	14.2	--	53.2	12.8	--
137 min. of anes.	48.8	14.5	--	52.7	11.6	--
Case 41						
Preinduction	--	--	--	53.7	11.8	1.0
25 min. of anes.	54.8	13.0	2.2	56.6	11.1	2.7
55 min. of anes.	51.6	19.8	2.7	57.6	14.2	2.9
85 min. of anes.	56.1	16.4	2.9	57.2	16.9	1.5
115 min. of anes.	56.3	15.0	2.7	58.1	13.8	2.7
24 hr. postoperative	37.3	17.4	2.2	39.9	13.3	2.9

Table 6. Amount of Fluothane used and recovery time according to the duration of anesthesia

Duration of anesthesia	Amount used (per hour)	Recovery time
Less than 30 minutes	62.4 cc. (4)[a]	32.6 min. (5)
30 to 60 minutes	34.2 cc. (16)	23.3 min. (19)
60 to 90 minutes	30.5 cc. (11)	29.4 min. (12)
90 to 120 minutes	30.3 cc. (6)	41.2 min. (6)
120 to 150 minutes	28.3 cc. (3)	29.3 min. (3)
150 to 180 minutes	27.1 cc. (1)	38.0 min. (1)
More than 180 minutes	28.3 cc. (1)	45.0 min. (1)

[a]Number in parenthesis indicates cases recorded.

Table 7. Effect of change in Fluothane concentration on respiratory rate

Case: Thoroughbred Surgery: Removal of fractured sesmoid

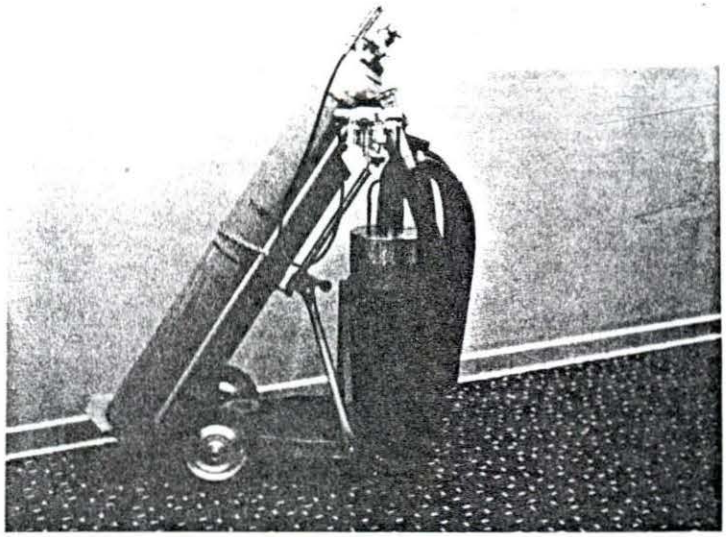
Weight: 1150 lbs. Premed.: 300 mg. Sparine

Sex: Gelding Induction: 3 grams Surital

Time	Resp.	Pulse	Comment
Pre	15	36	No premed.
Pre	11	44	After 300 mg. Sparine
10:00	--	--	Induction
10:10	4	48	----------
10:15	8	44	Eye reflexes returning
10:20	12	40	30 sec. vaporization
10:25	10	48	Nystagmus returning (30 sec. vaporization)
10:30	6	46	No Nystagmus
10:40	11	44	Nystagmus returning
10:42	--	--	30 sec. vaporization
10:45	3	44	----------
10:50	6	46	----------
10:53	14	42	Strong Nystagmus
10:55	--	--	15 sec. vaporization
11:00	5	44	Nystagmus gone
11:05	8	46	Nystagmus returning
11:10	12	40	Strong Nystagmus
11:13	--	--	15 sec. vaporization
11:15	4	45	----------
11:25	8	42	----------
11:38			Machine off-procedure over

Fig. 1. Total anesthetic machine with Fluotec vaporizer mounted on the oxygen cart

Fig. 2. Anesthetic machine with ether bottle vaporizer and separate oxygen cart



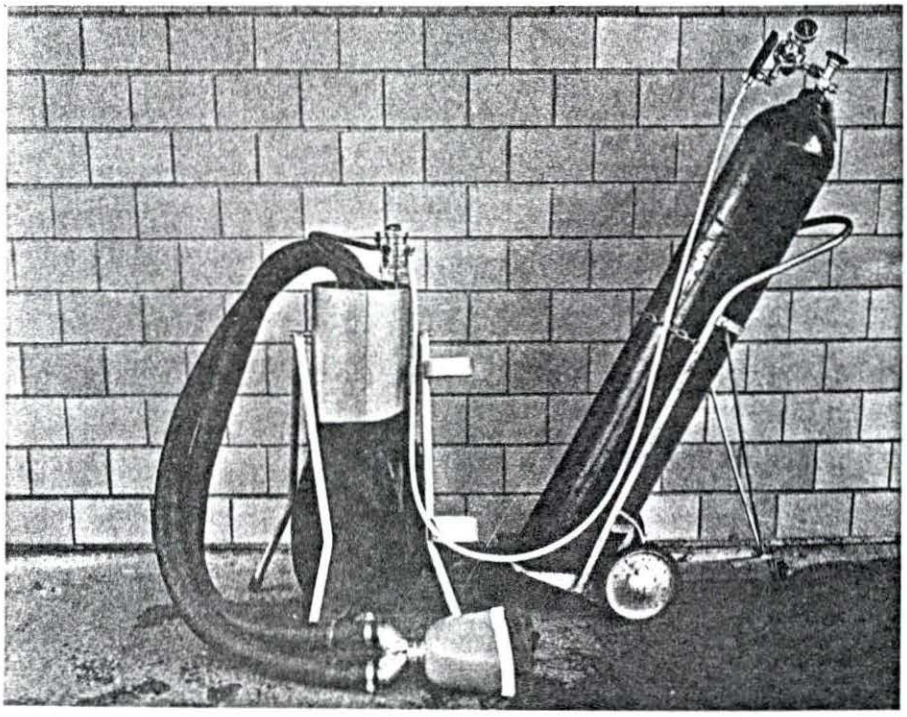
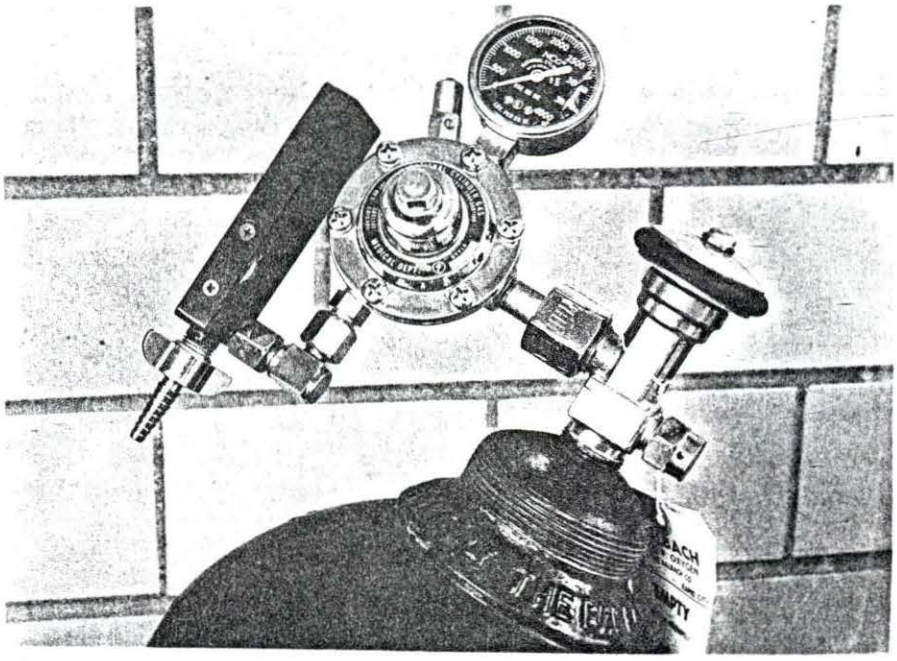


Fig. 3. Oxygen regulating valve

Fig. 4. Oxygen flow meter



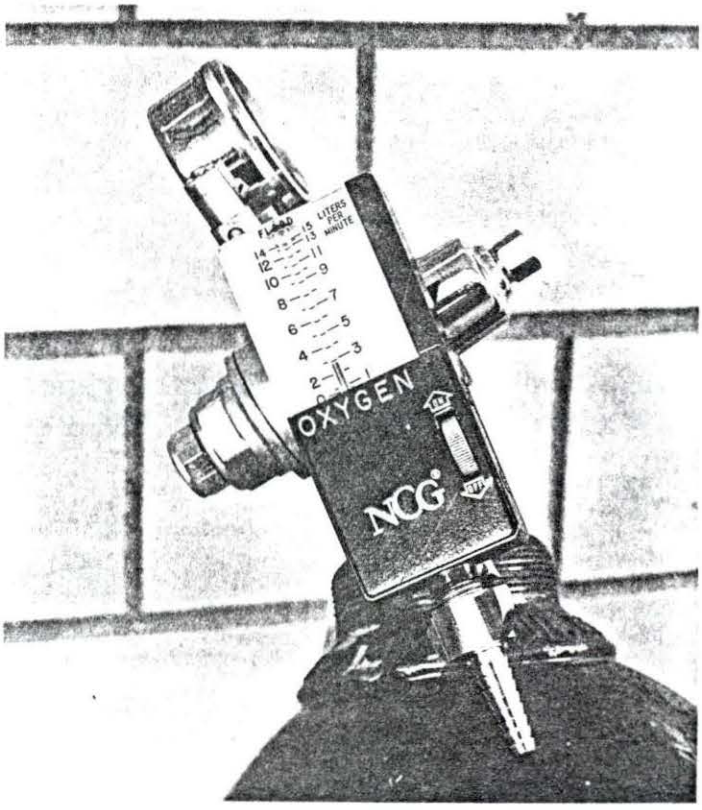

FLOW
LITERS
PER
MINUTE
OXYGEN
NCG

Fig. 5. Vaporizers used with the anesthetic machine. On the left is the Fluotec vaporizer and on the right is the ether bottle vaporizer

Fig. 6. The top on the ether bottle vaporizer showing the control valve and the various settings

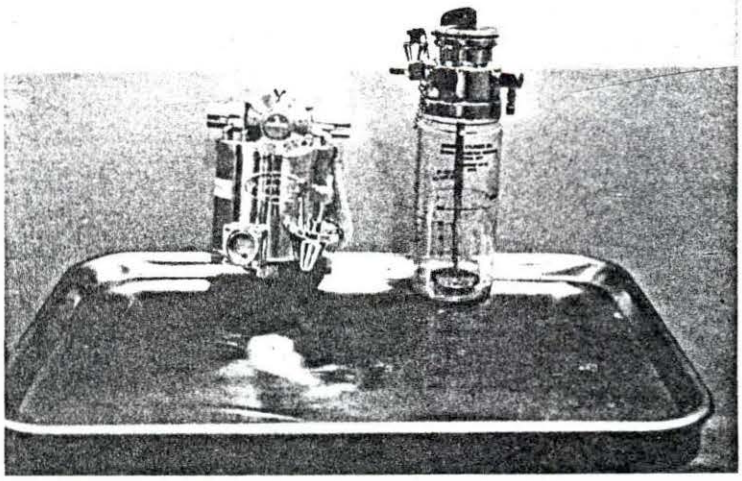
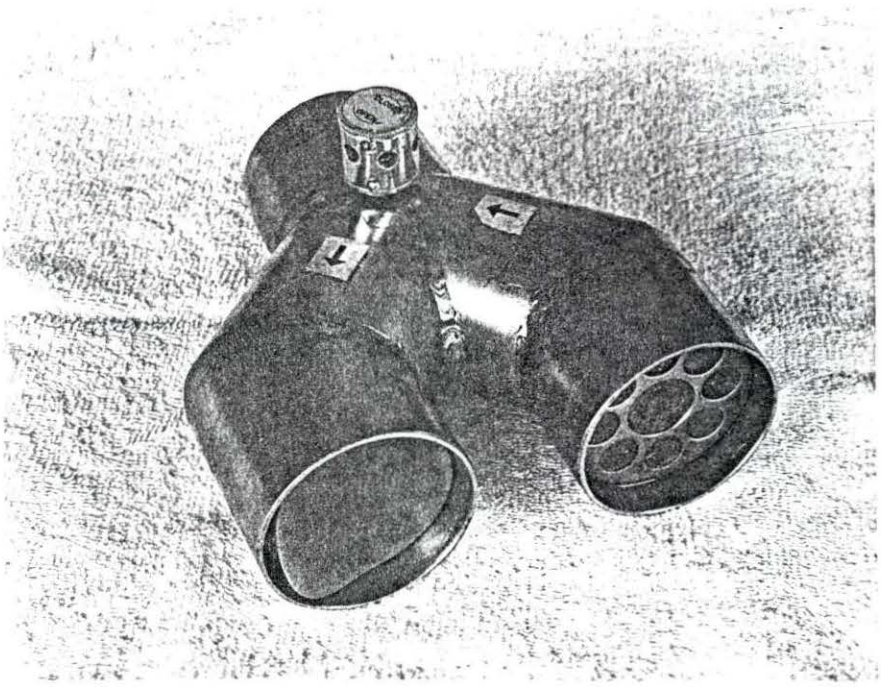


Fig. 7. The yoke which connects the inhalation and exhalation tubes to the face mask. Note the one way valves

Fig. 8. The face mask



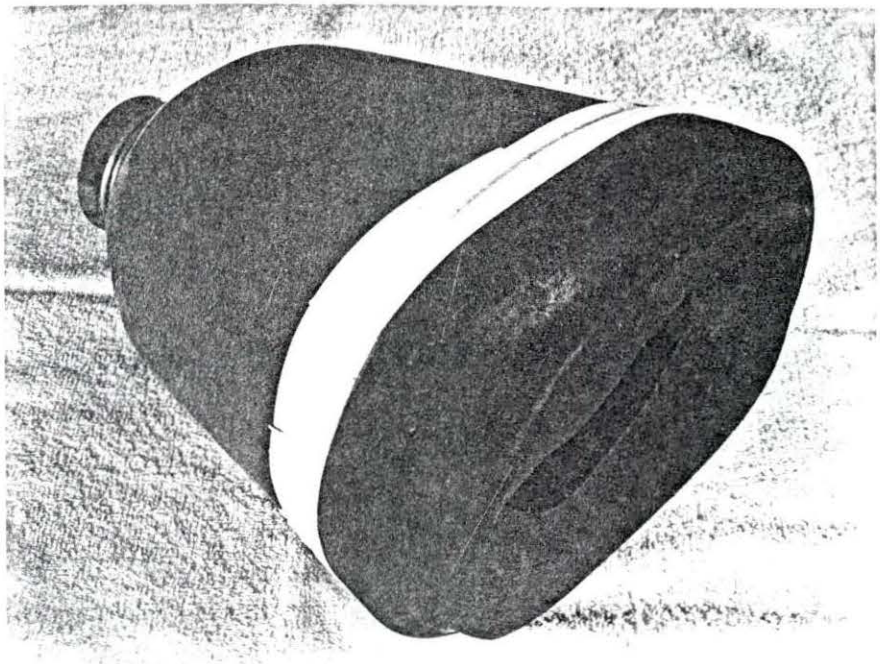
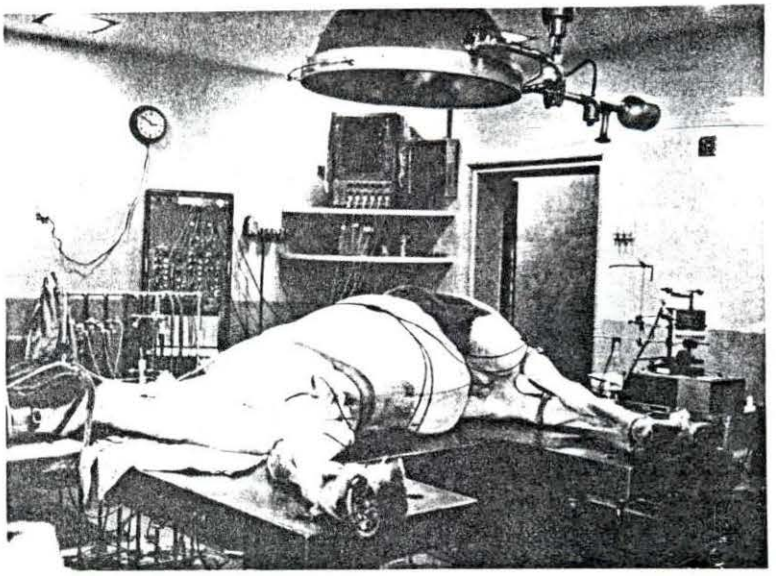


Fig. 9. Horse with electrocardiogram leads. Recording equipment is in the background.

Fig. 10. Six channel direct recording machine



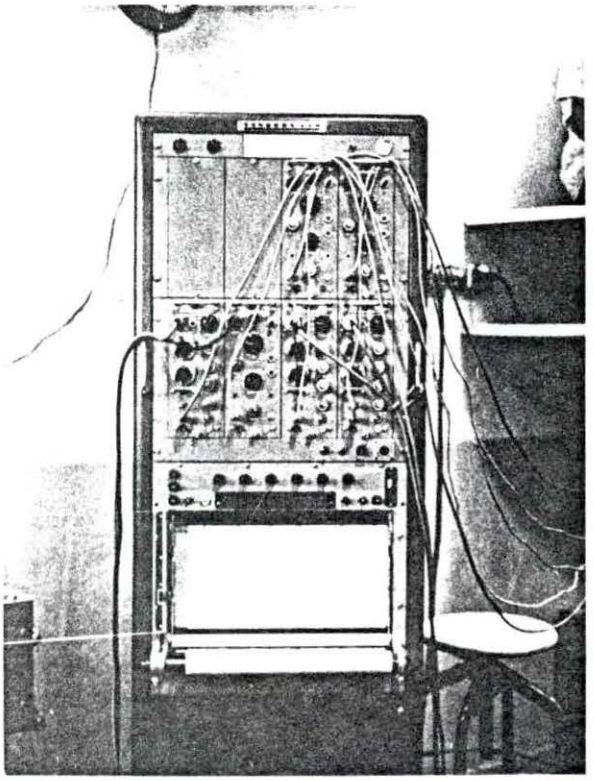
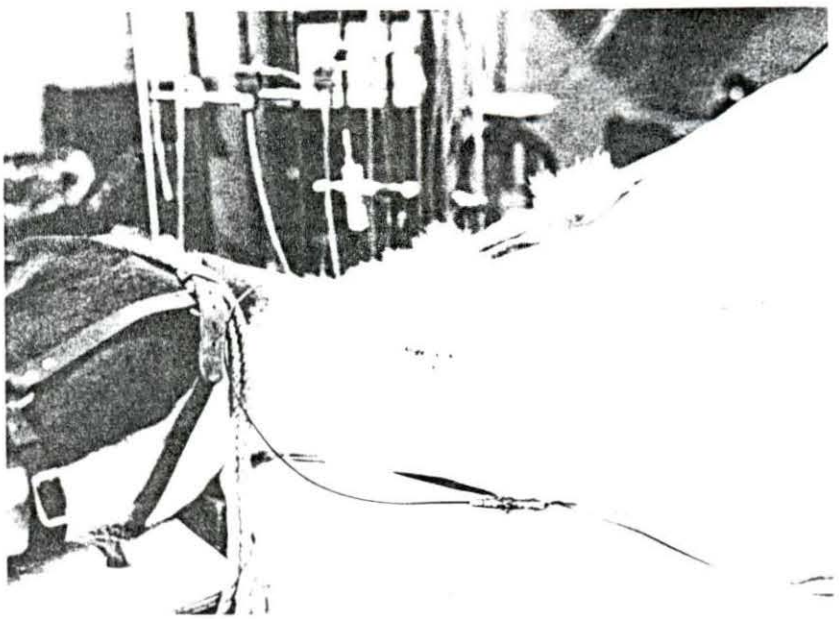
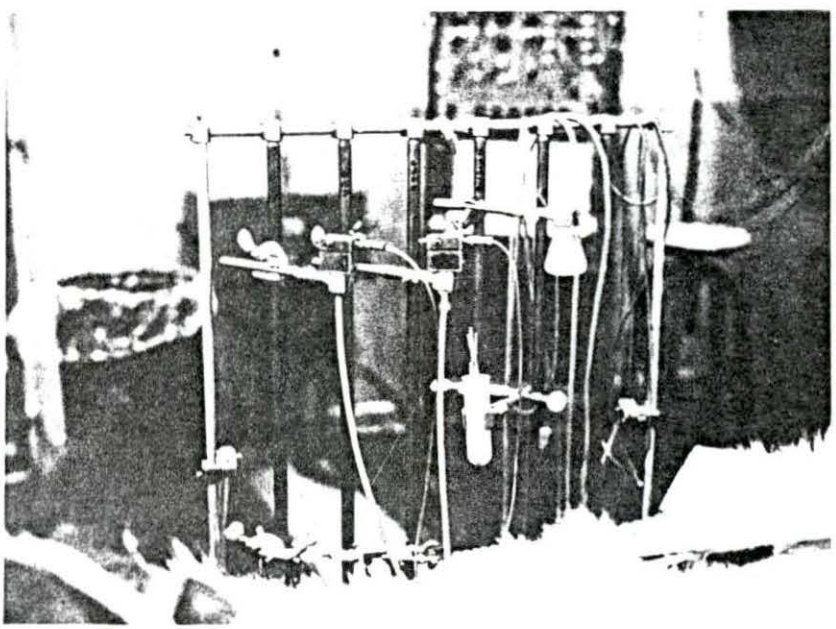


Fig. 11. The valves and catheters which were used to record blood pressure.

Fig. 12. Pressure transducers used in recording blood pressure and respiratory rate

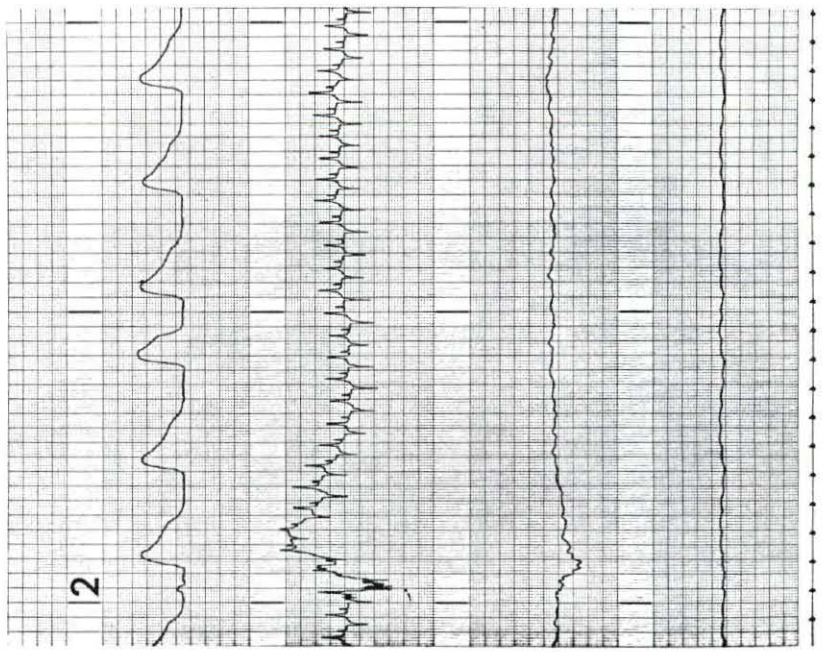




Figs. 13 through 18 are tracings of electrocardiogram, venous blood pressure, arterial blood pressure and respiratory rate of a horse during Fluothane anesthesia. The top line represents respiratory rate, the second line is the electrocardiogram, the third line is venous blood pressure, and the bottom line is arterial blood pressure.

Fig. 13. (1) This is a preinduction tracing. Respirations are 16 per minute; heart rate is 48 and irregular; venous blood pressure is 19 mm. of Hg.; arterial blood pressure is 111 mm. of Hg

Fig. 14. (2) Four minutes after induction was begun; respirations are 18 per minute; heart rate is 78 per minute (the rise in the tracing is due to movement by the horse); venous blood pressure is 20 mm. Hg; arterial blood pressure is 104 mm. Hg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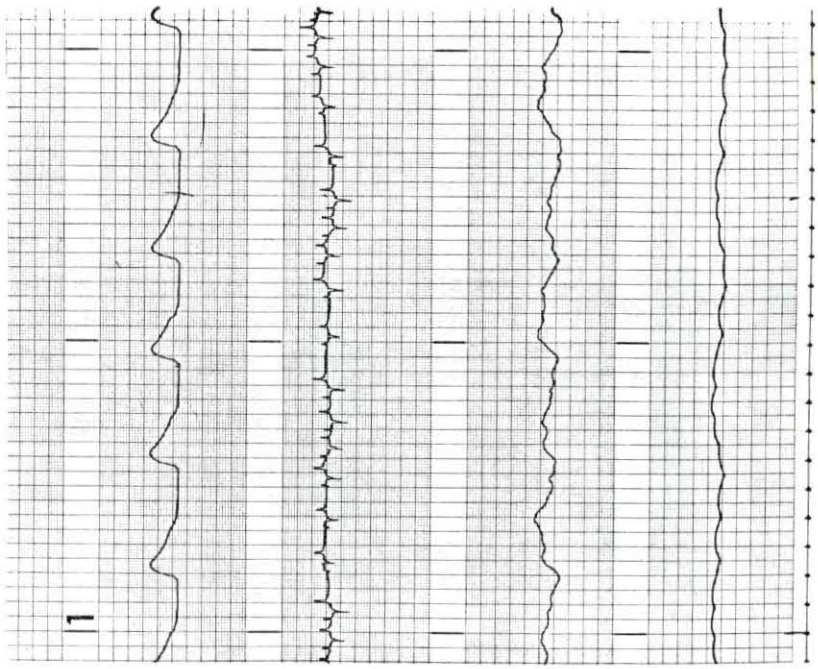
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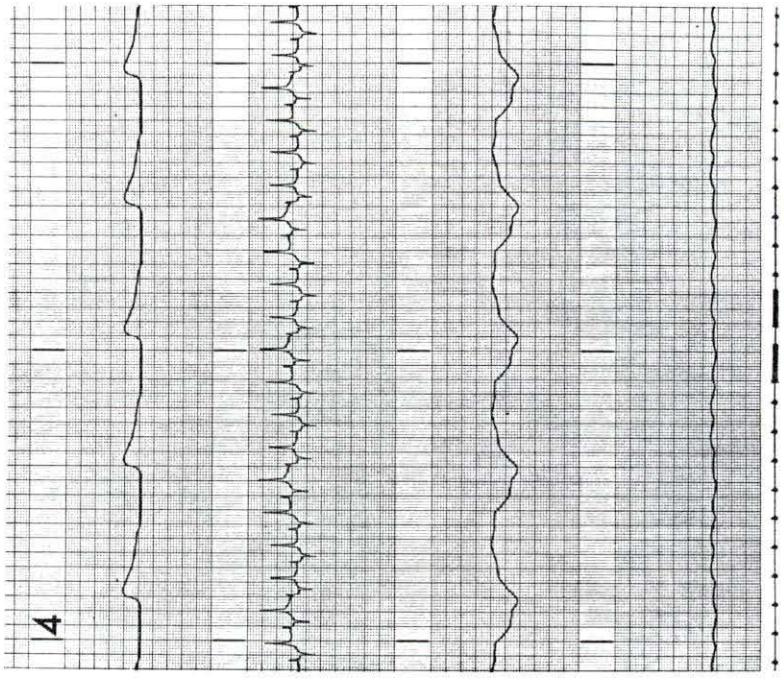
Fig. 15. (3) Eight minutes after induction was begun. Respirations are 12 per minute; heart rate is 66 per minute; venous pressure is 14 mm. of Hg; arterial pressure is 82 mm. of Hg

Fig. 16. (4) Eleven minutes after induction was begun, induction is complete. Respirations are 14 per minute; heart rate is 50 per minute; venous pressure is 20 mm. Hg; arterial pressure is 62 mm. Hg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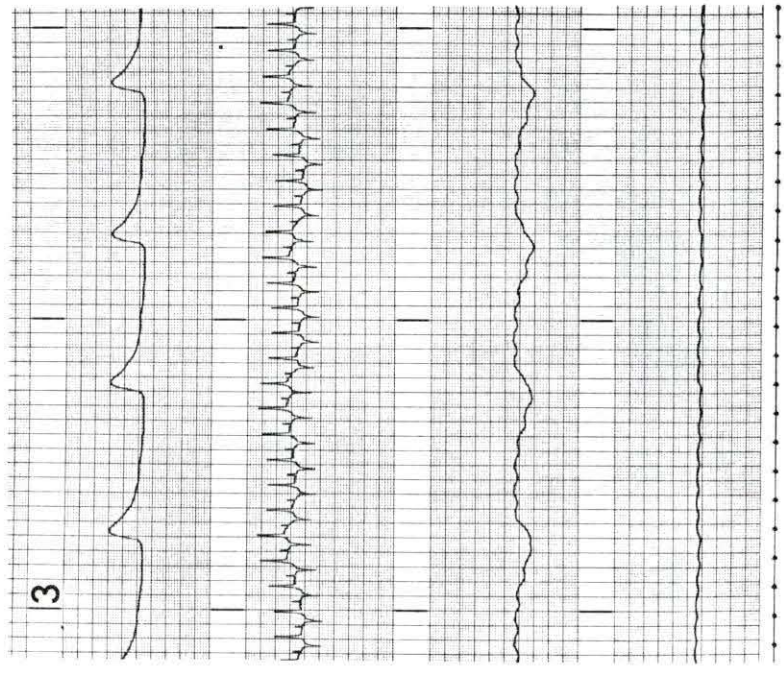
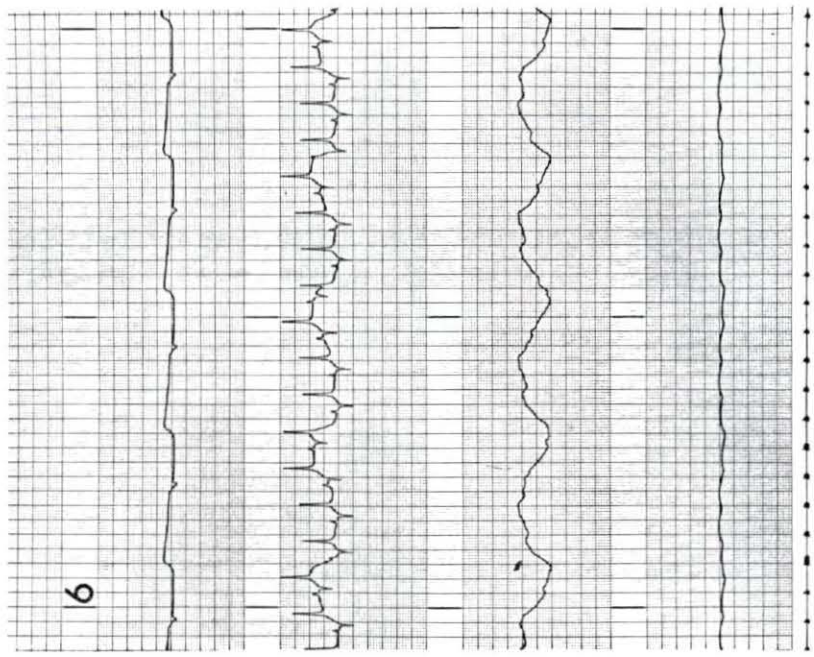

3

Fig. 17. (5) Twenty-one minutes after induction was begun. Respirations are 16 per minute; heart rate is 51 per minute; venous pressure is 20 mm. Hg; arterial pressure is 76 mm. Hg

Fig. 18. (6) Thirty-one minutes after induction was begun. Respirations are 14 per minute; heart rate is 48 per minute; venous pressure is 21 mm. Hg; arterial pressure is 96 mm. Hg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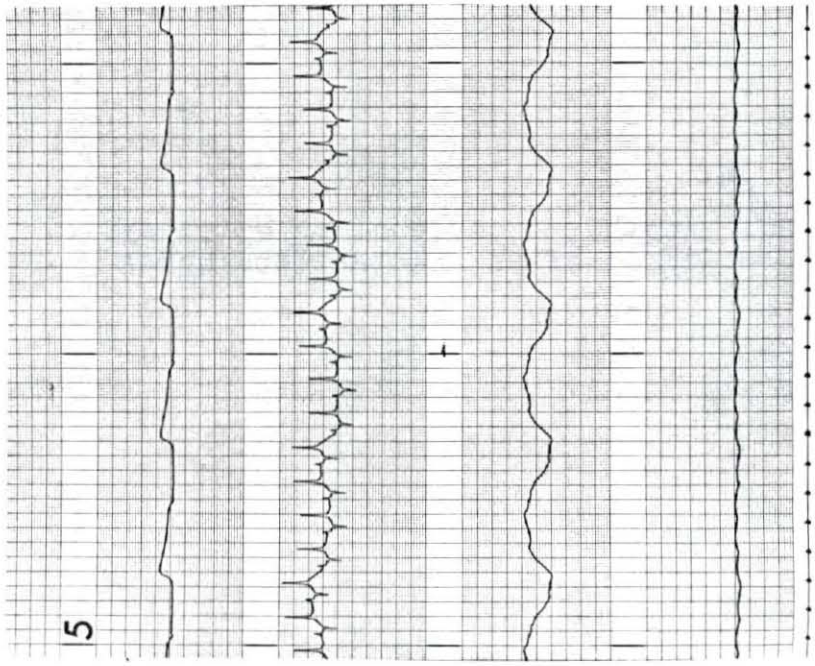
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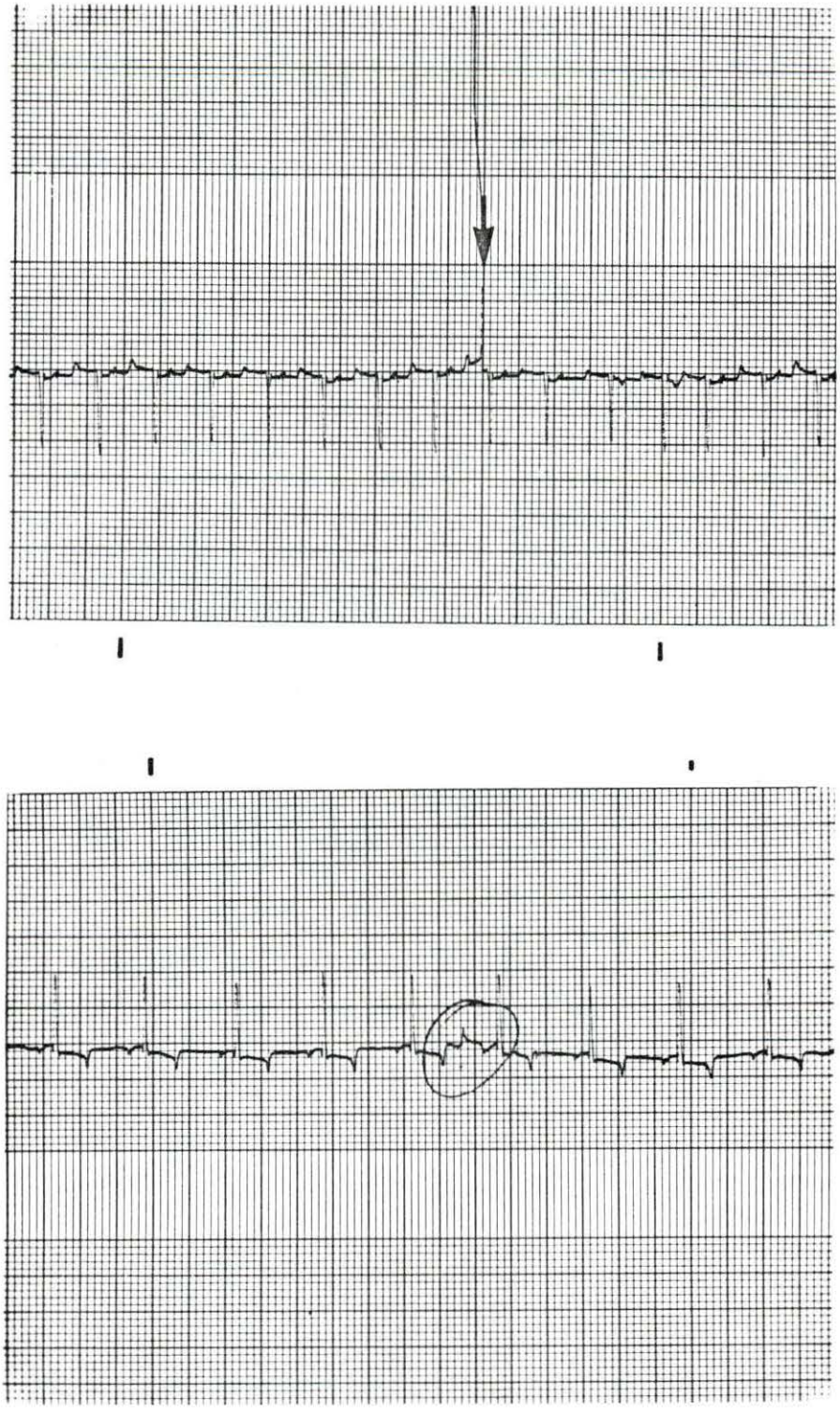
Fig. 19. Electrocardiogram of an anesthetized horse showing an extra systole at the arrow

Fig. 20. Another example of an extra systole (encircled area) of an anesthetized horse



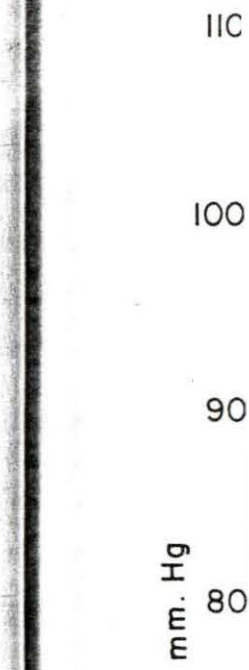
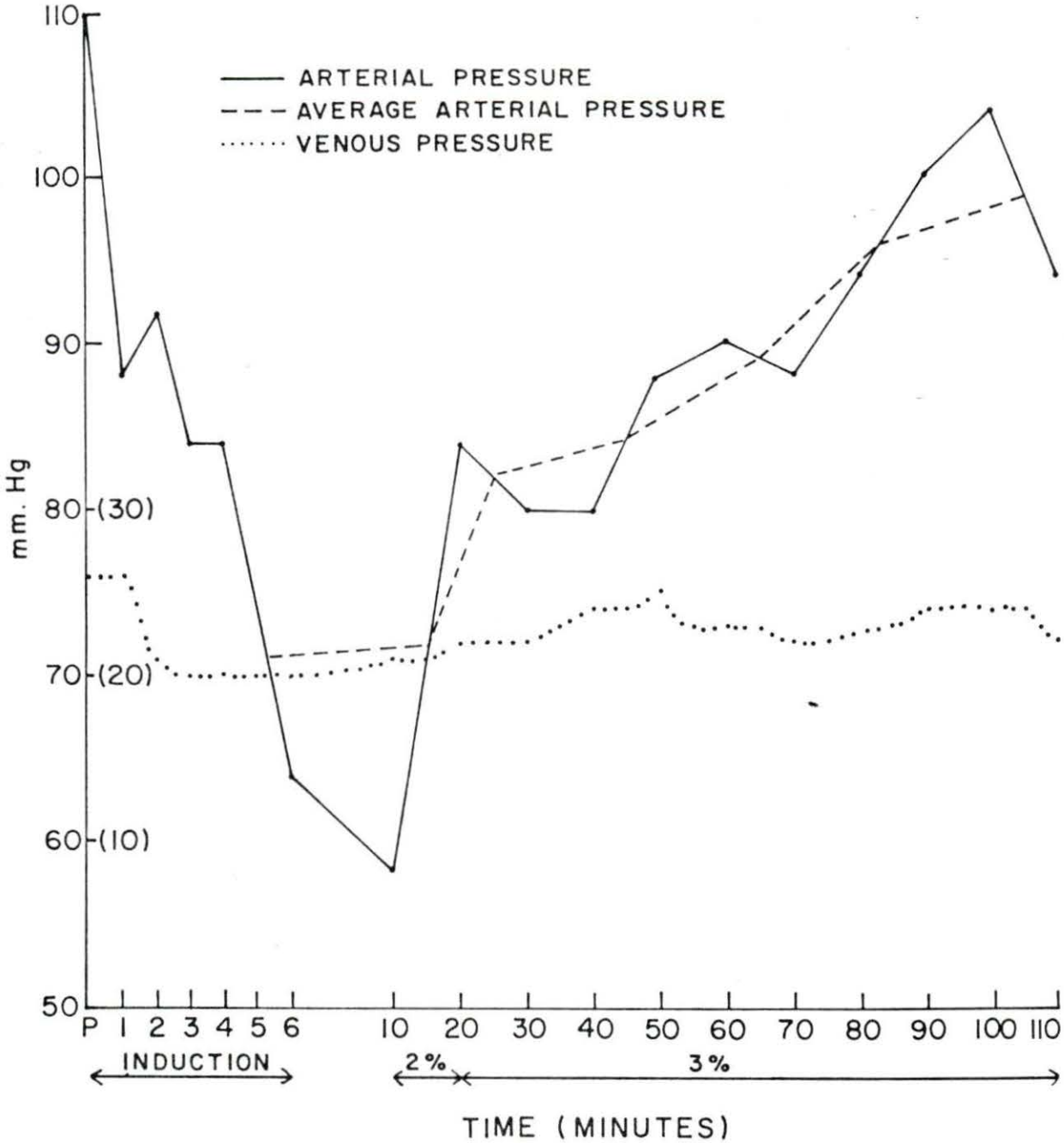


Fig. 21. This shows the blood pressure response in a horse which is receiving a constant concentration of Fluothane. The arterial pressure drops rapidly during induction and then increases during maintenance. There is a slight decrease in pressure when the concentration is raised from two per cent to three per cent, but the trend of increasing pressure continues.

Venous pressure decreases slightly with induction and then remains only slightly below the preinduction level during maintenance.

BLOOD PRESSURE NO. I

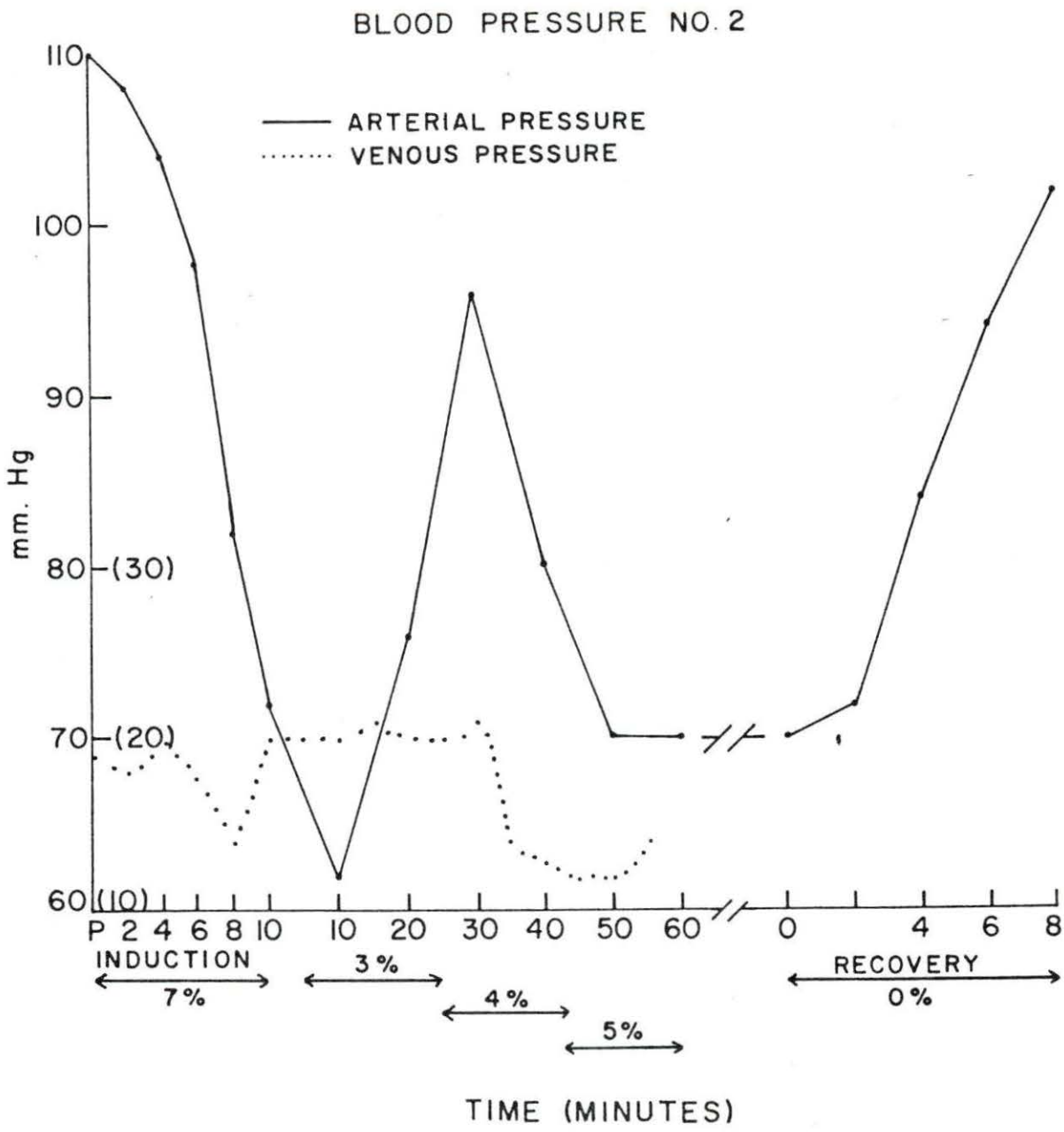


NUMBERS IN PARENTHESIS ARE FOR VENOUS PRESSURE

Fig. 22. The usual rapid fall in arterial blood pressure is seen in this horse followed by a gradual increase. The concentration of Fluothane is increased from three per cent to four per cent, and the response is a fall in pressure. Anesthesia was not conducted long enough for a response to the increase to five per cent to be seen.

A very rapid increase in arterial blood pressure is noted when the horse was no longer receiving Fluothane. In only eight minutes there was an increase of 32 mm. Hg during which time the horse was breathing atmospheric air only.

Venous blood pressure increased slightly during early induction and then fell near the end of induction. Thereafter it appeared to parallel the changes in arterial pressure.



NUMBERS IN PARENTHESIS ARE FOR VENOUS PRESSURE

Fig. 23. The horse shows a blood pressure response which was similar to others in the study

mm. Hg

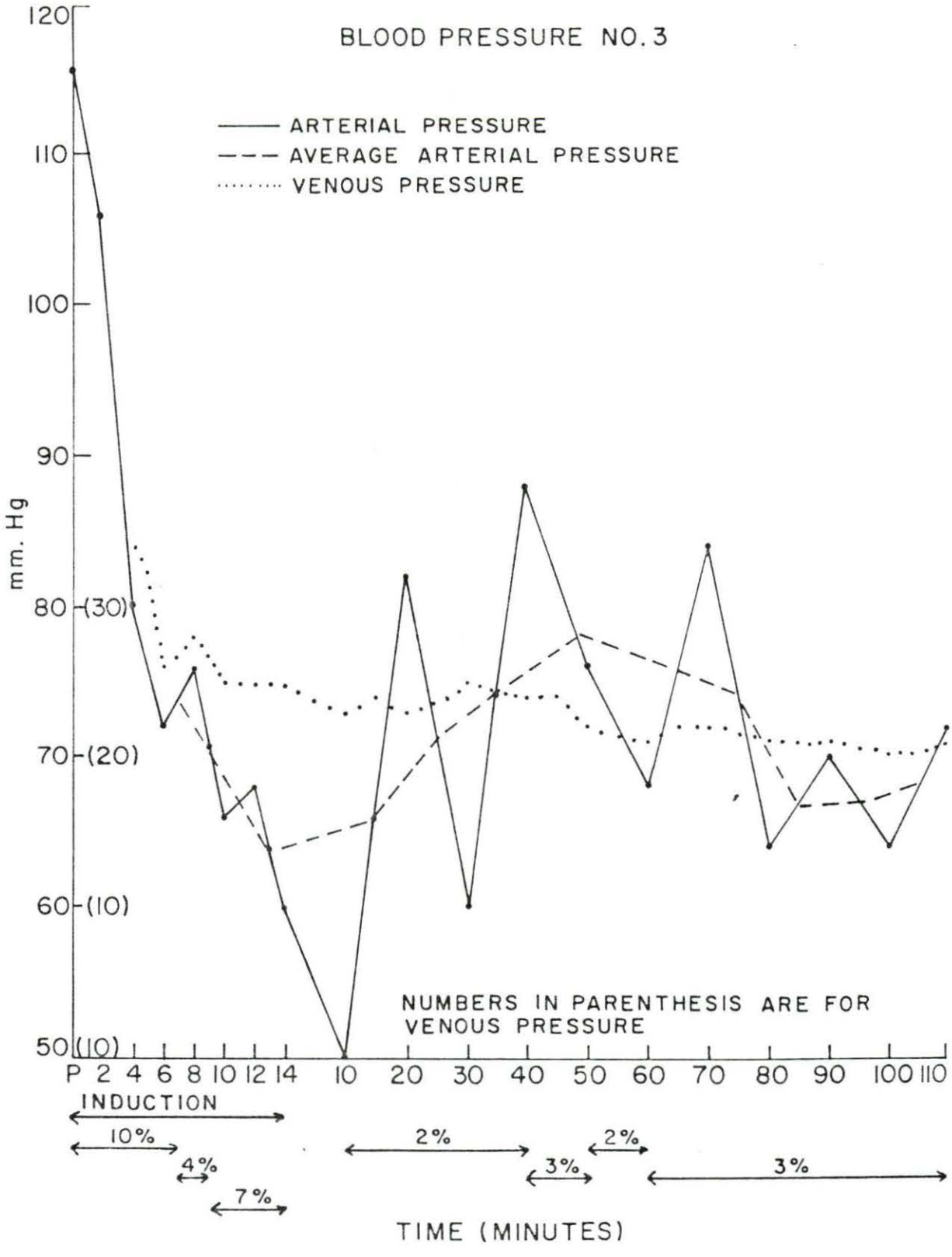

BLOOD PRESSURE NO. 3
ARTERIAL PRESSURE
AVERAGE ARTERIAL PRESSURE
VENOUS PRESSURE
mm. Hg
120
110
100
90
80 (30)
70 (20)
60 (10)
50 (10)
NUMBERS IN PARENTHESIS ARE FOR VENOUS PRESSURE
P 2 4 6 8 10 12 14 10 20 30 40 50 60 70 80 90 100 110
INDUCTION
10%
4%
7%
2%
3%
2%
3%
TIME (MINUTES)

Fig. 24. In this case the ether vaporizer was used. The X's at the bottom of the graph indicate the times when the vaporizer was on for a few seconds.

The blood pressure curve is not different from others in this series, except that it rises to above the preinduction level near the end of anesthesia.

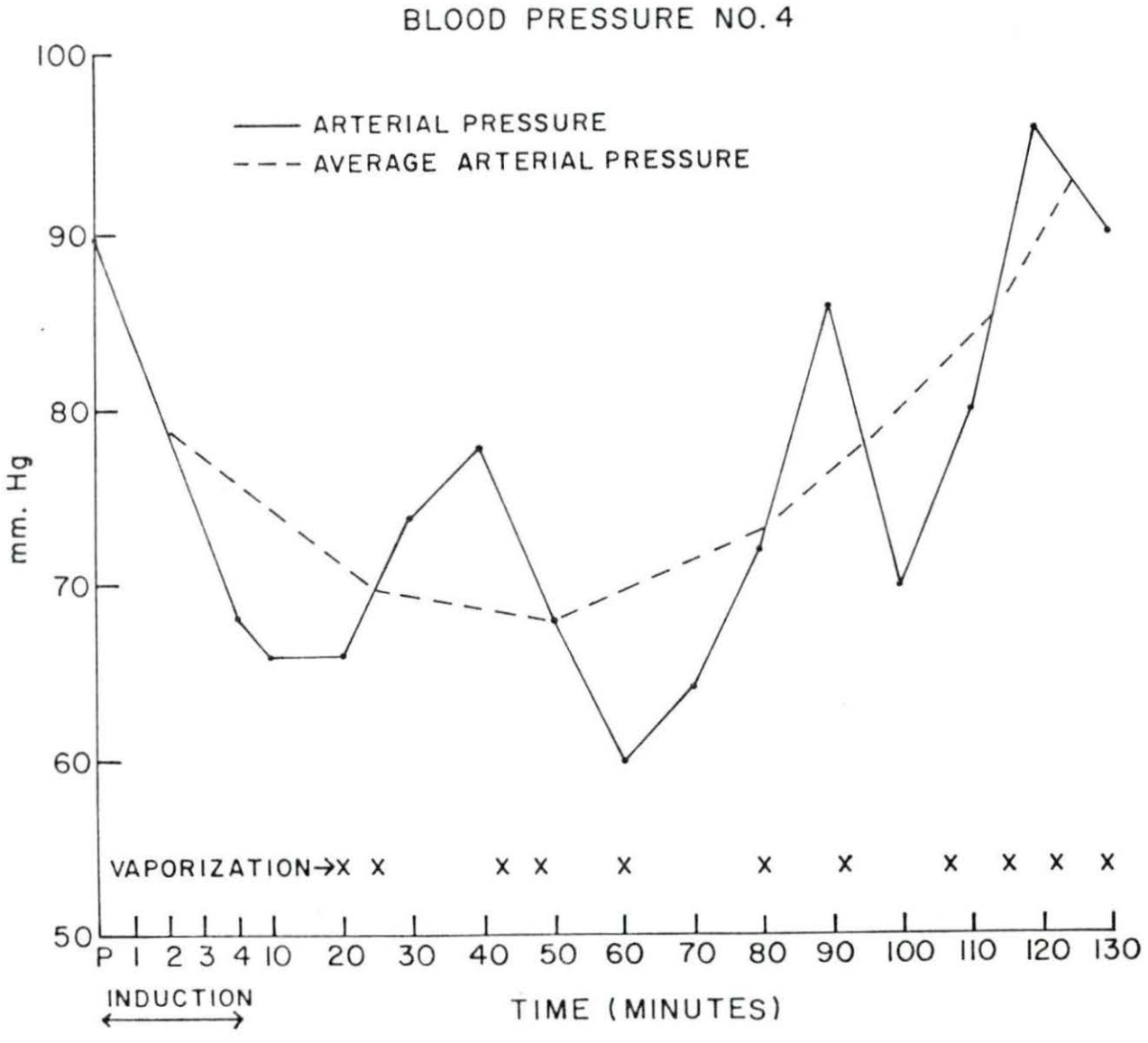
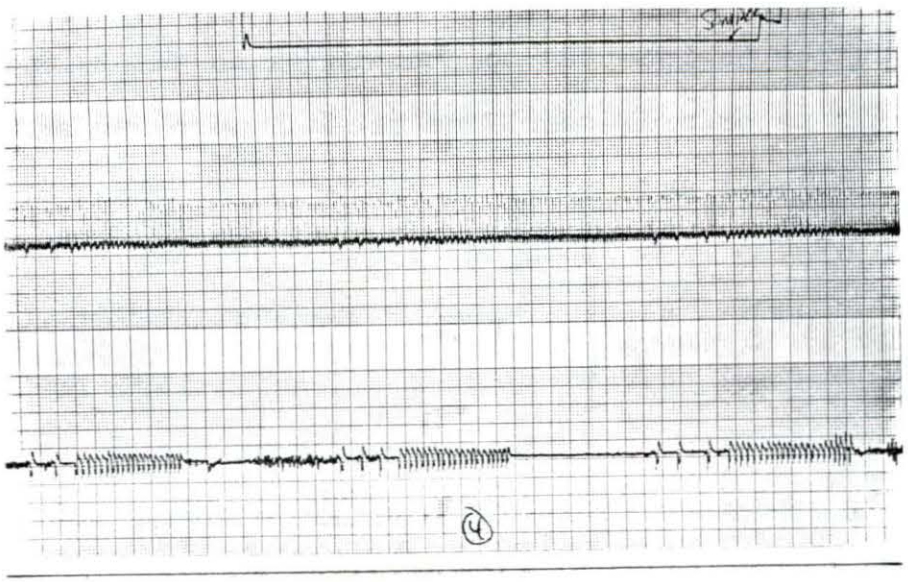

BLOOD PRESSURE NO. 4
ARTERIAL PRESSURE
AVERAGE ARTERIAL PRESSURE
mm. Hg
100
90
80
70
60
50
VAPORIZATION→X X X X X X X X X X X X
P 1 2 3 4 10 20 30 40 50 60 70 80 90 100 110 120 130
INDUCTION
TIME (MINUTES)

Fig. 25. The bottom line of the tracing is a recording of respirations. The recording shows a regular rate of breath holding observed during Fluothane anesthesia in a horse. The recording machine was running at one mm. per second. Each small square is one mm.

Fig. 26. A recording of respiratory rate (bottom line). Note the two different rates of respiration. The recording was made at one mm. per second. Each small square is one mm.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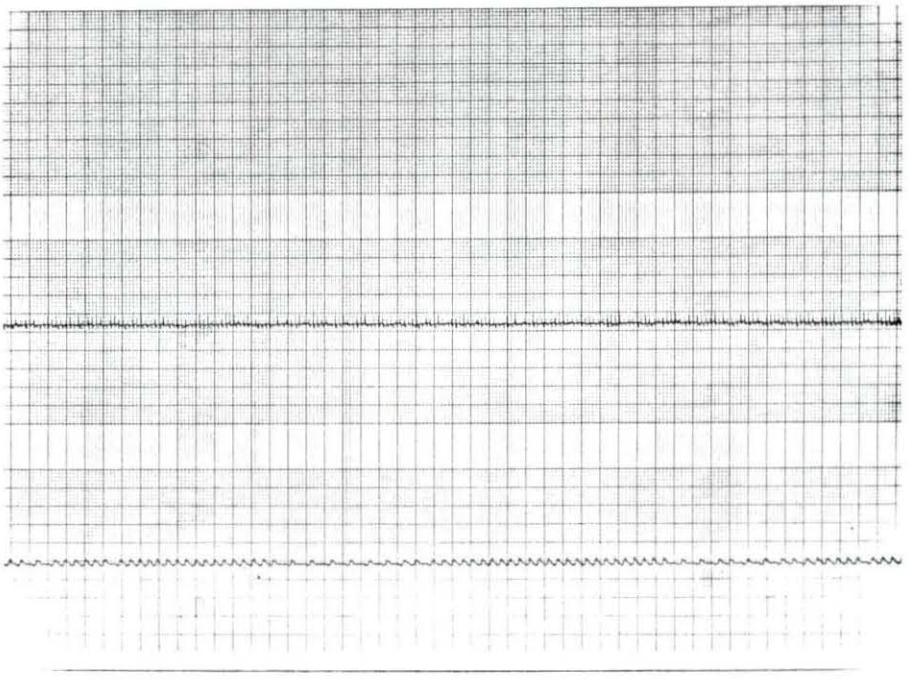

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