High carbon dioxide tension (PCO_2) and the incidence of cardiac arrhythmias in rapidly growing broiler chickens

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The purpose of this investigation was to determine whether two-week-old rapidly growing broiler chickens with high metabolic activity have an increased risk of the development of heart failure three to five weeks later. The incidence of cardiac arrhythmias was assessed in broiler chickens with either a relatively high carbon dioxide tension (PCO_2) or a low PCO_2 in their venous blood. Their electrocardiograms (ECGs) were measured when the birds were between five and seven weeks old by means of a biotransplant which allowed them to move freely. Premature ventricular beats were observed in all the birds, but the largest numbers were observed in birds that had had a high PCO_2 when they were two weeks old.

PREVIOUS studies have demonstrated that at high altitudes the low oxygen tension in the air (hypoxia) is responsible for the development of mountain sickness in men and in domestic animals such as poultry, cattle and pigs (Tucker and others 1975, Sillau and others 1980, Anand and others 1990). The symptoms of mountain sickness are pulmonary hypertension, right ventricular hypertrophy, dilatation of the heart, and generalised oedema. Ventricular arrhythmias associated with right ventricular enlargement have also been observed at extreme altitudes (Karliner and others 1985). Nowadays, however, these signs can also be observed in broiler chickens at sea level (Peacock and others 1989, Scheele and others 1991). They are probably the result of modern selection programmes that focus on rapid growth, a high rate of metabolism, and a low feed-conversion ratio. These factors are known to induce hypoxaemia (a low oxygen tension in the blood) in broiler chickens (Scheele 1996). It has been suggested that hypoxaemia may trigger a cascade of processes, including the development of pulmonary hypertension, right ventricular hypertrophy, dilatation of the heart, and generalised oedema (Scheele 1996). It is hypothesised that rapidly growing broiler chickens develop high metabolic activity and hypoxaemia at an early age and that they are risk factors for the development of heart failure. To test this hypothesis the bodyweight, and the carbon dioxide tension (PCO_2) and oxygen tension (PO_2) in the venous blood of rapidly growing broiler chickens were measured when they were two weeks old. When the birds were five to seven weeks old their electrocardiograms (ECGs) were studied to assess the prevalence of cardiac arrhythmias.

MATERIALS AND METHODS

Birds

Three hundred male broiler chickens were selected from a population that had a rapid growth rate combined with a low feed conversion ratio. It had previously been suggested that this experimental broiler line might have a high risk of developing heart failure (Scheele 1996). They were housed in a room (19 x 14·5 m) which was temperature controlled. The birds were gradually exposed to an ambient temperature below their zone of thermoneutrality as follows: during their first two-and-a-half weeks of life, the room temperature was gradually reduced from 30°C to 15°C, and it was then maintained at this temperature until the end of the experiment. This low temperature forced all the birds to increase their metabolic rate and their oxygen consumption. The birds were given continuous light during the first day, and they were then subjected to alternating periods of four hours light and two hours darkness. The birds were fed ad libitum with a standard broiler diet.

Blood gas parameters and bodyweight

At two weeks of age (days 15 to 16), the carbon dioxide tension (PCO_2) and oxygen tension (PO_2) in the birds' venous blood was measured with a blood gas analyser (ABL 605; Radiometer systems), and they were weighed. From the 300 birds two groups of 72 birds were selected, one consisting of the birds having the highest PCO_2 levels, the other of the birds having the lowest PCO_2 levels. From each group nine birds were selected at random for the implantation of a transmitter.

Surgery

The chickens were anaesthetised by the subcutaneous injection of 0·4 ml 2 per cent lidocaine hydrochloride. The transmitter (TA11CTA-F40; Data Sciences) was then implanted subcutaneously. Its two electrodes were fixed to the ventral and dorsal surface of the sternum in order to minimise contact with muscular tissue and to obtain high quality ECG recordings even during sustained physical activity (Korte and others 1999). After surgery the birds were returned to their cages. The experiments were performed at least six days after the implantation of the transmitter.

Heart rate acquisition and processing

A personal computer with the LABPRO data-acquisition system (Data Sciences) was used to measure the ECG parameters. The experimental birds were housed individually in floor cages (38 cm long x 97 cm wide x 60 cm high) next to a cage containing five birds in visual contact. Just before the experiment, the experimental bird was moved to a smaller cage (38 x 55 x 30 cm) with a receiver board. When they were four weeks old the birds were placed in this smaller cage for four hours to habituate them to this novel environment. The output from each transmitter was received by antennae mounted in a RLA 2000 receiver board (Data Sciences). The ECG was sampled for periods of 11 minutes when the birds were five, six and seven weeks old. The mean number of arrhythmic events (ventricular premature beats) in the groups of birds with high and low PCO_2 during these periods were counted by a cardiophysiologist who was unaware of the differences in PCO_2 tension. Premature beats often occur before the next expected beat of the dominant cycle should have occurred and are followed by a compensatory pause (Sgoifo and others 1997); they are ectopic beats, and as this name suggests they are heart beats arising in any focus within the heart other than the sino-atrial node (Armstrong 1978).

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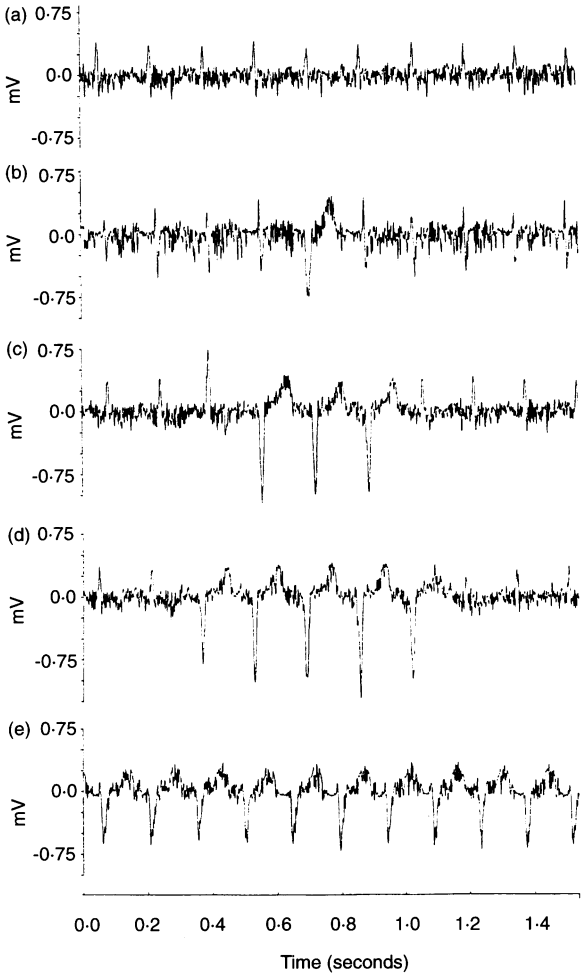

FIG 1: Telemetric electrocardiogram (ECG) tracings from rapidly growing broiler chickens. (a) normal rhythm, (b) ventricular premature beat, (c) three ventricular premature beats (triplet), (d) five ventricular premature beats, (e) ventricular tachycardia

Statistics

The numbers of ventricular premature beats in the broiler chicks with low and high PCO_2 levels were analysed by the Mann-Whitney U-test. The levels of PCO_2 in the two groups were also analysed with the Mann-Whitney U-test. A probability level of $P<0·05$ was considered to be significant.

RESULTS

Blood gas parameters

The group with a high PCO_2 had a significantly ($P=0·0006$) higher mean (se) PCO_2 tension [68·24 (3·52) mmHg] than the group with a low PCO_2 [52·19 (0·64) mmHg]. The PO_2 was significantly lower ($P=0·0006$) in the group with a high PCO_2 than in the group with a low PCO_2, 33·66 (0·96) and 43·03 (1·28) mmHg, respectively.

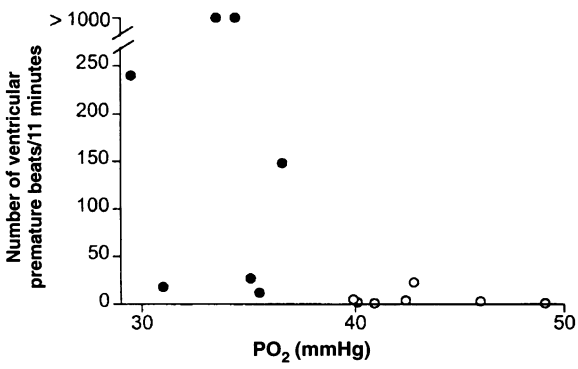

FIG 3: Relationship between birds with low (●) or high (○) PO_2 values in venous blood at the age of two weeks and the number of ventricular premature beats recorded at the age of five to seven weeks

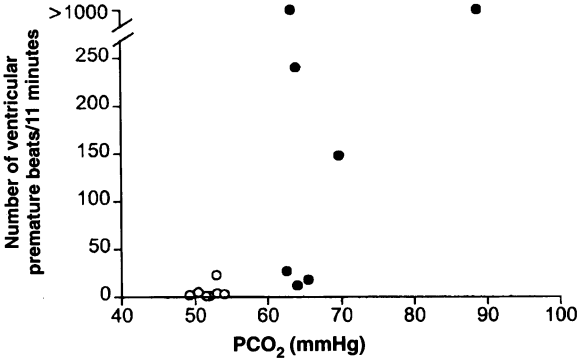

FIG 2: Relationship between birds with high (●) or low (○) PCO_2 values in venous blood at the age of two weeks and the number of ventricular premature beats recorded at the age of five to seven weeks

Electrocardiograms

The ECG data from four birds were not used because of the poor quality of the signal. Premature ventricular beats were observed in all the experimental birds (Fig 1). The number of ventricular premature beats was significantly higher in the group with a high PCO_2 and low PO_2 than in the group with a low PCO_2 and high PO_2 ($P=0·0023$) (Figs 2 and 3). Two birds with a high PCO_2 died within 18 hours after ECGs had been recorded in which there were sustained ventricular tachycardias.

Bodyweight

At two weeks of age the mean (se) bodyweights of the groups of birds with high and low PCO_2 were respectively 544·9 (22·1) g and 509·0 (15·7) g. There was no clear relationship between these bodyweights and the numbers of ventricular premature beats (Fig 4).

DISCUSSION

The results of this study agree with earlier reports that a high prevalence of ventricular arrhythmias can be observed in broiler chickens (Olkowski and others 1997, Olkowski and Classen 1998). The most frequently observed disturbances of the rhythm were premature ventricular beats. However, to the authors' knowledge this is the first time that it has been

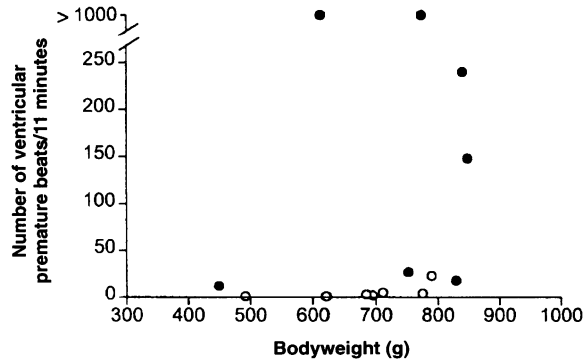

FIG 4: Relationship between the bodyweight of birds with high (●) or low (○) PCO_2 at the age of two weeks and the number of ventricular premature beats recorded at the age of five to seven weeks

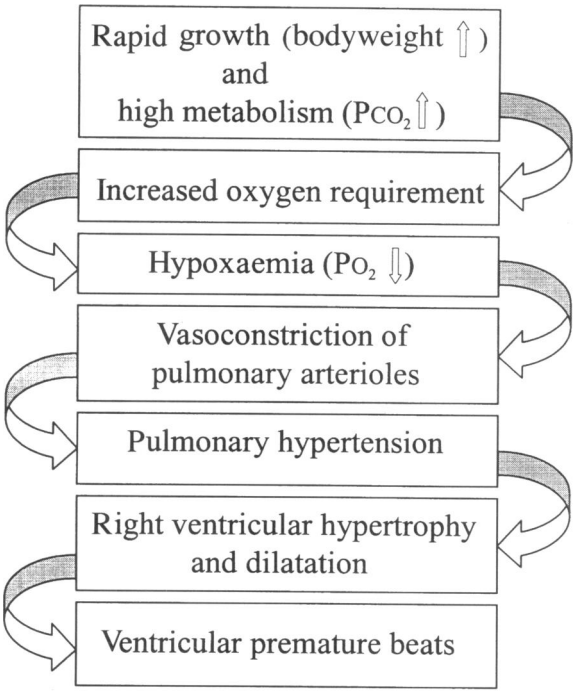

FIG 5: Proposed hypothesis for the relationship between rapid growth and high metabolic rate, and cardiac arrhythmias

reported that the PCO_2 in the venous blood of broiler chickens at two weeks of age may be associated with a high incidence of cardiac arrhythmias when they are five to seven weeks of age. Premature ventricular beats were observed in all the experimental birds. They can be attributed partly to the low ambient temperature in which the chickens were reared, which would have demanded a higher metabolic rate and a higher oxygen requirement, two factors which speed up the development of heart failure as a result of hypoxaemia (Scheele 1996). If rapidly growing broiler chickens are exposed to a normal ambient temperature it has been reported that the incidence of premature ventricular beats increases with age, ranging from 1 per cent of the birds at two weeks to 8·9 to 17 per cent at five to six weeks (Olkowski and others 1997, Olkowski and Classen 1998).

Many investigators have found direct and indirect evidence of a positive relationship between hypoxaemia, pulmonary hypertension and right ventricular hypertrophy in rapidly growing broiler chickens (Julian and others 1986, 1987, Peacock and others 1989, 1990). These phenomena follow each other in time and the authors hypothesise that they may ultimately lead to 'sudden death'. This hypothesis is explained in detail below (Fig 5). Although the aetiological factors underlying cardiac arrhythmias and sudden death are not completely understood, there is growing evidence that factors such as rapid growth, low feed conversion ratio, low ambient temperature, high altitude etc, may play a crucial role in hypoxaemia-induced heart failure. In the rapidly growing birds with a relatively low PCO_2 only a few arrhythmic events were observed (Fig 4), suggesting that rapid growth in itself is not necessarily associated with heart failure, but that in combination with a high metabolic rate and high PCO_2 it can be.

Rapid growth and a high metabolic rate result in a high PCO_2 tension in the blood of the bird. A high metabolic rate requires a rapid supply of oxygen to the metabolically active tissues. An increased requirement for oxygen in anabolic processes, in addition to the normal requirement for oxygen for maintenance processes may exceed the maximum capacity of the lungs and blood circulation for the supply of oxygen (Scheele 1996), and lead to a critically low PO_2 in the blood (hypoxaemia). This condition may be further worsened by the bird's inability to breathe normally owing to its weak ribs and infolding (Julian and others 1986). The transport of oxygen to the tissues can be maintained temporarily by an increased production of red blood cells and an increased heart rate and blood flow. To increase oxygen intake from the inspired air the pulmonary arterioles are constricted. The right ventricle of the heart has to respond to the increased resistance by increasing the pulmonary arterial blood pressure. This pulmonary hypertension has to be overcome by an extreme systolic force from the right ventricle. The right ventricle cannot produce a high pressure for a long period without being damaged. Hypertrophy and dilatation of the right ventricle in response to pulmonary hypertension has been observed many times in broiler chickens (Julian and others 1986, Peacock and others 1989, 1990). In accordance with the idea that rapid growth results, via a sequence of steps, in ventricular hypertrophy, it was shown that rapidly growing broiler chickens more often developed right ventricular hypertrophy than slower growing chickens (Peacock and others 1990). This right ventricular hypertrophy could be prevented by restricting their diet, and hence their growth rate (Peacock and others 1989). Feed restriction is also associated with an improvement in the oxygen tension in the blood (Reeves and others 1991).

The results of this study have shown that a high PCO_2 tension in the venous blood of broiler chickens at the age of two weeks is associated with a high incidence of cardiac arrhythmias at the age of five to seven weeks. Cardiac arrhythmias were observed in all the birds kept at a low ambient temperature. The further genetic selection of broiler chickens for rapid growth rate and a low feed conversion ratio, without consideration of the early development of vital organs like the lungs and heart, may be expected to lead to an increased prevalence of cardiac failure in birds kept under normal temperature conditions. This development may cause serious losses in the broiler industry and may have adverse effects on the birds' welfare. It is concluded that a low PCO_2 in the venous blood may be a useful tool for genetic selection, whereas a high PCO_2 may be a useful indicator of poor welfare.

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Interdental acrylic stabilisation of canine tooth root and mandibular fractures in a dog

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A two-year-old labrador had bilateral open fractures of the apical region of the mandibular canine tooth roots and the adjacent mandible. The fractures were reduced and held in place with an interdental acrylic splint, after which the tooth roots and mandible healed directly.

FRACTURES of the mandible are a common occurrence in dogs, and are usually associated with trauma (Umphlet and Johnson 1990). A complication rate of 42 per cent has been described for open fractures, with dental malocclusion, infection and non-union being the most common problems (Umphlet and Johnson 1990). The treatments available for mandibular fractures include the use of wire fixation, external skeletal fixation, intramedullary pin fixation and bone plating (Roush and Wilson 1989, Umphlet and Johnson 1990, Lewis and others 1991, Boudrieau and others 1994). However, damage to the tooth roots is an important problem associated with many of the traditional methods for fixing fractures of the mandible, and a higher complication rate has been associated particularly with the use of intramedullary pins (Umphlet and Johnson 1990). This problem has led to the investigation of interdental acrylic splints for stabilising mandibular fractures (Kern and others 1993, 1995), but there is little information about their use in clinical practice.

This report describes the treatment of a dog with bilateral fractures of the mandibular canine tooth root and associated fractures of the horizontal rami of the mandible by using an acrylic splint to fix the fractures.

CLINICAL HISTORY

A two-year-old male labrador, weighing 35 kg had injured its jaw while running off the leash. The dog was found depressed and in pain. The rostral region of the horizontal ramus of the mandible just caudal to the canine teeth was fractured bilaterally (Fig 1), and the oral mucosa was broken so that the fracture was open.

The dog was anaesthetised and the jaw was radiographed (Fig 2). The apical segments of the roots of the mandibular canine teeth, and the associated horizontal ramus of the mandible were fractured bilaterally. The pulp chambers of the canine teeth were wide, because the dog was young.

The dog was prepared for general anaesthesia by passing the endotracheal tube through a pharyngotomy incision immediately rostral to the hyoid apparatus, to facilitate the reduction and stabilisation of the fractures. The crowns of the mandibular teeth were cleaned with an ultrasonic scaler in preparation for the placement of the acrylic splint. To improve the bonding of the dental acrylic to the crowns of the teeth, the enamel of all the teeth rostral to the fractures and the premolars bilaterally were etched for one minute with phosphoric acid (Etch Gel 40 per cent; Henry Schein), rinsed and dried. The fracture site was then lavaged with sterile saline and the rostral part of the mandible was reduced anatomically. The fractures were initially stabilised with circumferentially applied 26-gauge interdental wire (Kern and others 1993), to facilitate the application of dental acrylic. Dental acrylic (Jet Repair Acrylic; Lang Dental) was then applied to the teeth which had previously been etched and wired (Figs 3 and 4). The dog was then allowed to recover. Incremental doses of butorphanol (Torbugesic; Fort Dodge) 0·2 mg/kg were given by intramuscular injection perioperatively for analgesia. Antibiotic cover was given initially with cephazolin (Cephazolin; Schein Pharmaceutical) at 20 mg/kg intravenously four times a day, and then with amoxycillin-clavulanic acid (Clavamox; SmithKline Beecham) at 15 mg/kg orally three times a day for 10 days after surgery.

The dog was more comfortable on the day after surgery, and readily ate a normal quantity of food, and was discharged from the hospital with instructions to be fed only soft food. One month after the surgery, radiographic views of the mandible showed that the fractures were healing. Two months after surgery, the oral mucosa adjacent to the splint was observed to be ulcerated. The fractures of the tooth roots and

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