Ever since the advent of general anaesthesia in 1846, the subject of anaesthetic mortality has been a source of considerable debate and discussion. In the late 1880s, the Hyderabad Commissions concluded that chloroform was a completely safe anaesthetic agent in the human species. The Lancet commissioned its own study and this was probably the first epidemiological investigation of the effects of anaesthetic agents in any species. On the basis of animal experiments, the Hyderabad Commissions had concluded that chloroform was a safe agent in man but the Lancet Commission challenged these findings. They concluded that death under chloroform anaesthesia was 8.7 times more likely than death under ether anaesthesia, whereas chloroform was only administered 6.1 times more often than ether. Whilst the members of the commission failed to establish the relative safety of ether or chloroform, they focused attention on the role of human error in the aetiology of anaesthetic deaths. It took the greater part of 50 yr before the real problems of anaesthetic deaths and their prevention became the subject of intense study by a number of anaesthetists throughout the world. It was only during that time that the real value of properly maintained anaesthetic records was emphasized by Waters. However, it was not until 1954 that a well-designed and executed survey was reported by Beecher and Todd. They collected data on 600 000 patients from 10 university hospitals over a 5-yr period. The report caused considerable controversy, in that it reported a considerably higher mortality in patients that had received the newly introduced muscle relaxant drugs compared with those that did not.

One of the major problems in surveys of anaesthetic mortality is its actual definition and how this relates to surgical and overall mortality; these problems have been discussed by Duberman and Bendixen. With the refinement of both anaesthetic and surgical techniques, patients with extensive pathology are being anaesthetized who in a previous era would not have undergone surgery. Hence, it is extremely difficult to compare anaesthetic mortality on a historical basis.

In 1973, following a computer analysis of deaths associated with anaesthesia, Marx and his colleagues reported that the mortality within the first 7 days of surgery was 1.9%. They considered that two main factors determined the mortality rate—the physical status of the patient and the skill and judgement of the physicians. Two-thirds of the deaths were considered to be preventable. In a further survey from Australia in 1975, Bodlander showed that the incidence of deaths associated with anaesthesia was one in 502 (0.2%). The number of deaths attributable to anaesthesia showed a marked fall from 20% to 3.7% of the total mortality over the 10-yr period of the survey. The definitive work on anaesthetic mortality in the UK has been published by Lunn and Mushin. They reported that one in 166 (0.6%) of patients died within 6 days of surgery but only one in 10 000 deaths (0.01%) is directly attributable to anaesthesia. They went on to report that, in a much larger number of 1800 deaths, anaesthesia may play some part in one in 1700 (0.06%), and they suggested that this could, in large measure, be avoided. The events that caused these deaths do not appear to have changed over the past 30 yr.

In a study of 7306 patients in Denmark by Pedersen and colleagues in 1990, it was reported that one in 1800 (approximately 0.05%) died during anaesthesia, one in 730 (>0.1%) during the recovery period, and the overall hospital

© The Board of Management and Trustees of the British Journal of Anaesthesia 2001
mortality rate was one in 81 (1.2%). In an assessment of anaesthetic mortality, Keats suggested that ‘anaesthesia mortality has not decreased because we create new mechanisms of mortality at the same rate as we solve them’.10

In veterinary anaesthetic practice, it is extremely difficult to collect meaningful statistics on the subject of anaesthetic mortality, due to the diverse nature of veterinary practice and the absence of a Coroner’s Court system. Hence, there is no real need or incentive to record or report anaesthetic deaths. However, on the basis of scientific curiosity, a number of surveys have been reported and, overall, there is a greater interest in the subject over the past 10 yr.

Horses

Anaesthetic mortality in horses has always been considered to be relatively high compared with most other species and has been attributed to the size and bulk of the horse, and to its unique cardiopulmonary physiology as a highly evolved athletic animal. However, in a series of some 600 horses which had received chloral hydrate by the i.v. route, Wright and Hall reported only two deaths (0.3%).11 With the development of extensive gastrointestinal surgery in the horse, the mortality rate has risen and a rate of 1.18% has been recorded more recently.12 It is important to separate the animals undergoing elective surgery from those undergoing emergency abdominal surgery, which have extensive abdominal pathology, and are extremely hypovolaemic and in endotoxic shock. Resuscitation of these animals presents a massive challenge. In a series of horses reported in 1983 from Norway, a mortality of 33 in 1216 (2.7%) was reported but anaesthesia was responsible for only 0.8%.13 In a further study of 1314 equine general anaesthetics reported from a single centre in 1993 by Young and Taylor, the mortality was 0.68%.14 The main causes of death were ischaemic myopathy (which is similar to compartment syndrome), fracture of the cervical or long bones, and cardiac arrest. It was not until 1995 that accepted epidemiological principles were applied to anaesthetic mortality in horses. A confidential enquiry by Johnston and colleagues surveyed a total of 6255 equine general anaesthetics and reported an overall mortality of 1.6%.15 When abdominal surgery and foals were excluded, the rate fell to 0.9%. They identified a number of factors, which led to a higher mortality, including anaesthesia in the third trimester of pregnancy, emergency abdominal surgery, orthopaedic procedures involving internal fixation, and the administration of xylazine. Xylazine is a relatively nonspecific alpha2-adrenoreceptor agonist, which was the first one of that group of drugs to be used in domestic animals. It has similar cardiovascular effects to the other drugs in that group, but the actual cause of death after xylazine is uncertain. The risk of death also increased with the duration of anaesthesia, when it was carried out outside normal working hours, and in foals under 1 yr old. In a further single centre study, Mee and colleagues reported on a series of 2276 horses undergoing elective surgery under general anaesthesia.16 A death rate of 0.63% was attributable to surgery/anaesthesia but the rate for anaesthesia was only 0.08%. The cause of death in the one horse was cardiac arrest 15 min after induction of anaesthesia in which resuscitation was unsuccessful. Post-mortem examination failed to establish a cause of death. In contrast, in a further series of 995 horses undergoing emergency procedures, the same authors reported a mortality of 31.4%.17 In abdominal surgery, the gross mortality was 35.5% and in the non-abdominal surgery group it was 15.3%. The surgical/anaesthesia death rate was 4.3% in the abdominal surgical group and 2% in the other group. The main causes of death were cardiac arrest, uncontrollable massive haemorrhage, and irreversible endotoxic shock. In a later report in 2000, Johnston and his colleagues reported on 41 787 equine anaesthetics.18 The overall death rate was 1.9%. When abdominal surgery was excluded, the rate was 0.9% but, for abdominal surgery, it was 7.9%. The most common causes of death were cardiac arrest (33%), fractures (23%), and ischaemic myopathy (7%).

Small animals

In cats and dogs, there is a little more information available from surveys conducted over the past 50 yr, although the main information has been published in the past decade. A survey of 2912 anaesthetics administered in one institution, between 1955 and 1957, recorded a mortality of 1.1% in dogs and 1.8% in cats.12 A follow-up survey in 1979–1981 showed a reduction to 0.43% in dogs and 0.25% in cats. The main cause of death was attributed to human error leading to anaesthetic overdosage and to hypoxia. Equipment problems, hypothermia, and cardiovascular collapse were other causes of death. A survey of 10 000 feline anaesthetics in Scotland reported a death rate of 0.3%.19 The main causes of death appeared to be related to the failure to obtain accurate body weights of the animals, to use adequate and effective pre-medication, and to intubate the trachea.

In 1990, a survey of 20 814 dogs and 20 103 cats undergoing general anaesthesia in the UK reported a mortality of 0.23% in dogs and 0.29% in cats.20 However, when they were divided into two groups, on the basis of the absence or presence of pathology, a different situation was observed. In dogs, the figure was 3.12% with pathology and 0.11% without. In cats, a similar pattern was observed with a mortality of 3.33% with pathology and 0.29% without. There were few factors that could be highlighted as the main cause of death. However, the administration of xylazine was again associated with an exceptionally high mortality rate. Complications following tracheal intubation in the cats appeared to be associated with several deaths.

In a survey involving some 30 000 anaesthetics reported in 1992, a mortality rate of 0.11% was reported in dogs and 0.06% in cats.21 The most common cause of death was
cardiopulmonary arrest. A further single institution survey published in 1994 recorded a death rate of 0.43% in dogs and cats. Most of the deaths were associated with cardiac arrest and, due to the nature of the surgical condition, resuscitation was not attempted in some of these animals. A more recent survey was published in 1998 on anaesthesia in the dog and cat. Death occurred in 0.11% of 8078 dogs and in 0.1% of 8702 cats. Significant odds ratios were calculated for a number of factors including the association of cardiac arrest with xylazine administration in dogs. A modified ASA classification of patient status was adopted, and a classification of 3, 4, or 5 was also associated with an increased incidence of cardiac arrest in both species.

It would appear that the incidence of death associated with anaesthesia over a number of years has shown a reduction in most species. Whilst this may well have been associated with the development of ‘safer anaesthetic techniques’, it is most likely also to have been associated with attempts to reduce human error by improved training and wider use of sophisticated monitoring methods. However, with the developments in surgery, which have presented greater challenges to the anaesthetist, it remains to be seen whether further major improvements in mortality figures will occur in the foreseeable future.

R. S. Jones
University Department of Anaesthesia
University Clinical Department
The Duncan Building
Daulby Street
Liverpool L69 3GA
UK

References
3 Waters RM. The evolution of anaesthesia I and II. Proceedings of the Staff Meetings of the Mayo Clinic 1942; 17: 428–40

6 Marx GF, Mateu CV, Orkin LR. Computer analysis of postanaesthetic deaths. Anesthesiology 1973; 39: 54–9
8 Lunn JN, Mushin WW. Mortality associated with anaesthesia. Anaesthesia 1982; 37: 856
11 Wright JG, Hall LW. Veterinary Anaesthesia and Analgesia, 5th Edn. London: Baillière Tindall and Cox, 1961; 161
14 Young SS, Taylor PM. Factors influencing the outcome of equine anaesthesia: a review of 1,314 cases. Equine Vet J 1993; 25: 147–51
18 Johnston GM. Equine anaesthesia – a chance to cut is a chance to kill. Proc Assoc Vet Anaesth 2000; 1–2