

**Sir Keith Sykes**  
**MA MB BChir (Cantab)**  
**FFARCS FANZCA (Hon)**  
**FFA (SA) (Hon) DA**



Keith Sykes became a full-time lecturer at the Postgraduate Medical School and Consultant Anaesthetist at Hammersmith Hospital in 1958. He was promoted to Reader in 1967 and was Professor of Clinical Anaesthesia at the Royal Post-graduate Medical School and Hammersmith Hospital

between 1970 and 1980. He moved to Oxford in 1980 becoming the Nuffield Professor.<sup>ii</sup> He retired in 1991 and was knighted in the same year.

In 1956 Keith Sykes was Assistant Anaesthetics Registrar at University College Hospital, London, and he reported on a visit to the USA where he had tenure of a Fellowship in Anaesthesia at the Massachusetts General Hospital, Boston, 1954-5 [1, 2].

At that time, he thought that “the anaesthetist in America is still fighting an uphill battle for recognition. He has little to say in the clinical management of patients, and in some cases is not allowed to advise on the premedication or even the choice of anaesthetic which the surgeon orders him to deliver.” The problem was that the demand for anaesthetic services had significantly outstripped the supply of suitably qualified anaesthetists. Some of the problem was due to a maldistribution of practitioners but it had been calculated that another 18000 were needed. The nurse anaesthetists carried the main load and were supervised by the surgeons who then treated anaesthetists as technicians.

*[Pask and Mushin responded with a letter strongly dissociating themselves from my criticisms! – personal communication]*

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<sup>i</sup> Photograph courtesy of Andrew Farmery, Nuffield Department of Anaesthetics, Oxford.

<sup>ii</sup> J F Nunn. British Journal of Anaesthesia. 1999; 83(6): 916

He describes in some detail the types of anaesthetic agents used; cyclopropane was used but there were worries about its explosive potential in the dry areas; ethyl chloride was banned because of cardiac arrests in children, at high altitude nitrous oxide was insufficiently potent to provide adequate analgesia and there were “grave doubts” about the safety of muscle relaxants<sup>iii</sup>. A paper in 1959 compares anaesthesia with ether with anaesthesia using thiopental, nitrous oxide and an infusion of succinylcholine [3]. It is a clear exposition of the methods of anaesthesia used at the time. The procedures were cholecystectomy, common duct exploration or gastrectomy; “Respirations were in almost all instances unassisted throughout surgery with ether.” Of the 693 patients studied 50 died but there was no difference in the mortality rate, duration of surgery or duration of hospital stay between the two groups.. Hypotension was a problem during anaesthesia with ether and “the dangers of postoperative hypoventilation associated with the use of muscle relaxants are well recognised, but the observation of increased postoperative atelectasis came as a surprise.” [!]

[Personal comment from MKS: *This paper resulted from discussions with Beecher who had just published his paper with DP Todd in Ann Surg 1954;140:2. I could not find any errors in the methodology of their study that showed that muscle relaxants produced a five-six fold increase in mortality when compared with ether and he challenged me to prove that relaxants were as safe as ether. I therefore set up the randomized controlled trial and ran it for the last six months of my time in Boston. I believe it was the first RCT in anaesthesia and was very proud of it. It clearly demonstrated that hypotension occurred more frequently during ether anaesthesia (because, as we learnt later, some very sick patients had a depressed adrenal response) and also that pulmonary complications were more common in the relaxant group. I had wanted to use curare in the trial but Beecher vetoed its use because his study showed a higher mortality with curare than scoline. We therefore had to use a scoline drip. Surgery was entirely done by residents with a couple of year’s training and often took 6 hours and scoline doses approached 1500-2000mg so we attributed the pulmonary complications to prolonged hypoventilation from a type 2 block. In retrospect, John Bunker and I concluded*

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<sup>iii</sup> Briggs, B.D. Anesthesiology 1954;15:323

*that the high death rate in the B&T study was due to the failure of most American anaesthetists to use neostigmine after curare at that time.]*

Following this description of his overseas experience, like many of his academic successors, he published a case report, an article on delayed spinal analgesia complicating epidural analgesia. The bottom line of this paper was that “the common practice of administering a test dose followed by a five minutes waiting period may be without value.”[4]

## **Equipment, measurement and monitoring**

### **Equipment:**

1959 saw the first two papers (of about 20) on the subject of anaesthetic related equipment - they were both on the subject of non-rebreathing valves [5, 6]. The first described three valves with the goal of reducing rebreathing in the various breathing circuits in common use and the second was a review article on the subject.

This was followed by a letter to the BMJ in 1960 on the subject of resuscitation equipment [7]. He described the innovation of a resuscitation trolley for Wards (total cost £50). It had a typical floppy anaesthetic breathing bag which was provided with oxygen from a cylinder attached to the trolley – no self-inflating bag as we have today. However, in addition they did have a Porton bellows resuscitator<sup>iv</sup>. For airway management the trolley also contained a range of oropharyngeal airways and laryngoscopes. A mouth gag was also present and it was suggested that it could also be used as a rib spreader; sterile scalpels were included in the armamentarium and so it was expected that open-chest cardiac compression might be likely. The drugs contained in the trolley were calcium chloride, adrenaline, and methylamphetamine.

There was hardly one piece of equipment not examined (well, perhaps vaporisers). An air inlet valve for ventilation [8], equipment for tracheostomy care [9], rebreathing with Magill circuits[10, 11], accessories for humidifiers[12], a mixing device for expired air [13], plastic endotracheal tubes [14], a pressure-operated collect valve for respiratory studies [15]. All these before 1970; plastic endotracheal tubes were uncommon, carbon dioxide analysis was difficult and devices were very ‘mechanical’.

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<sup>iv</sup> Lucas, B. G. B., and Whitcher, H. W. (1958). Brit. Med. J., 2,887.

[Personal comment from MKS: *Rebreathing. My first paper on this problem was in 1959. At that time most anaesthetists simply squeezed the bag on the Magill attachment when doing short periods of controlled ventilation (e.g. an appendicectomy under thiopentone-N<sub>2</sub>O trilene-gallamine) and it seemed obvious to me that different timing of expiratory valve opening would alter the CO<sub>2</sub> elimination. I used to provide topical anaesthesia for Hugh-Jones and John West to do regional bronchial sampling down a rigid bronchoscope and managed to persuade John to let me have a couple of runs with my model lung in the mass spectrometer room; it was the first machine to be built in the UK. I also managed to persuade a surgeon to do his minor ops session in this room so that I could study the patients. This was before the days of consent forms! ]*

Keith Sykes was involved in the assessment of many diverse pieces of equipment. Between 1971 and 1980 a huge change took place and the equipment became more sophisticated. Evaluation of a lung ventilator performance analyser [16, 17], an evaluation of the IL-404 oxygen alarm monitor[18], a vortex-mixing membrane lung for open-heart surgery or for prolonged respiratory support [19-22], high frequency ventilation/ventilators [23-33], the classic Magill attachment [10, 11] and sterilization of ventilators [34].

High frequency ventilation: – In the 1980s a new form of lung ventilation emerged, high frequency ventilation (HFV), (respiratory rates of >150/min)<sup>v</sup>. Sykes and his team studied the technique in animals.

[Personal comment from MKS: *High frequency ventilation. The paper that sparked off our interest was Jonson A, Oberg PA, Sedin G, Sjöstrand U. (1971) High frequency positive pressure ventilation by endotracheal insufflation. Act Anaesthesiologica Scand (Supple) XLIII.*]

Chakrabarti and Sykes published a paper on the cardiorespiratory effects of increasing respiratory frequency in dogs [23]. Increased respiratory frequency

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<sup>v</sup> D. P. Schuster, M. Klain & J. V. Snyder. "Comparison of high frequency jet ventilation to conventional ventilation during severe acute respiratory failure in humans". Critical Care Medicine 1982; 10 (10): 625–630D.

with a reduction in tidal volume, was accompanied by a reduction in physiological deadspace, the proportions were such that the deadspace/tidal volume ratio increased. "The peak airway pressures were minimal at a frequency of 45 bpm" but, at frequencies of 60 bpm. and more, the lungs "failed to empty so that peak airway pressures were increased and cardiac output decreased." These frequencies are not really HFV. HFV was expected to solve all problems associated with high airway pressures and resulting lung damage; there were many varieties. In 1986 they (the Sykes team) studied "the effects of frequency, tidal volume and added deadspace on carbon dioxide clearance were measured during high frequency jet ventilation at 1, 3 and 5 Hz in dogs"; that is at 60/min,180/min and 300/min [26]; "for a given minute volume the clearance [of CO<sub>2</sub>] decreased with increase in frequency." It was concluded that "at 1 Hz, carbon dioxide elimination is governed by bulk flow, but at 5 Hz other mechanisms are important." They were not very happy with CO<sub>2</sub> elimination at higher frequencies (see [27]) ..."the clearance of carbon dioxide at 5 Hz was very inefficient compared with that at 1 Hz. It is concluded that, during HFJ [Jet] V, carbon dioxide is cleared most efficiently when the frequency is low enough for the delivered tidal volume to be greater than the volume of the morphological deadspace"; a conventional approach. Although frequency of ventilation is preset two parameters are dependent on anatomical and the physical nature of the chest, arterial CO<sub>2</sub> and tidal volume. Mortimer et al [28] highlighted a problem with HFV which was that the slow response of infra-red carbon dioxide analysers made it difficult to measure EtCO<sub>2</sub> and so the HFV was interrupted with normal ventilatory frequencies and thus enabled the assessment of arterial PCO<sub>2</sub> by measurement of the end-tidal CO<sub>2</sub>; a cunning approach to the problem! This was developed further in 1989 [31]; a flow controller in a computerized high frequency jet ventilator delivered either a single deep breath or a series of three deep breaths and thus enabled the end-tidal value to be measured. With an optimum deep breath "the P<sub>E</sub>CO<sub>2</sub> during the first deep breath was found to be similar ( $\pm 0.2$  kPa) to the PaCO<sub>2</sub> immediately before the onset of deep breaths."

The second parameter, tidal volume, was addressed in Young's paper [29]. A pneumotachograph was positioned in the expiratory limb of the breathing circuit and enabled the gas volumes, true I:E ratios and mean driving pressures to be determined.

They not only addressed the problem of measuring ventilatory parameters but they also investigated whether HFV improved lung 'repair' in a

rabbit model of hyaline membrane disease [30]. Saline lavage of the lungs produced surfactant-depletion (a model of the neonatal respiratory distress syndrome). Animals treated with high frequency oscillation (HFO) at 15 Hz [900 resps/min] were compared with rabbits treated with controlled mechanical ventilation. HFO produced “significantly higher arterial oxygen tensions and end-expiratory lung volumes than those treated with CMV, but there was no significant difference between hyaline membrane scores”. There was no significant difference in mean survival times but some showed signs of recovery of surfactant function. There had been two previous publications with this rabbit model and conventional ventilation [35, 36].

Later in the 1980s came the new form of computerised axial tomography (CAT) - the nuclear magnetic resonance (NMR) scanner with its peculiar requirements, and so a ventilator for use in nuclear magnetic resonance studies [37]; then the wonderful multigas monitors, the Datex Capnomac [38], and the wonders of pulse oximetry – “Pulse oximetry: a “which” hunt?” [39-41] followed by the full power of the computerised world – the new microprocessor-controlled anaesthetic machine[42] and an evaluation of the Bruel and Kjaer monitor 1304 [43].

The 1980s were wonderful years for technological developments in anaesthesia.

### **Measurement**

Electronic monitoring in the 1960s was basic and in 1963 Sykes wrote an article on "Venous pressure as a clinical indication of adequacy of transfusion" [44].

*[Personal comment from MKS: John Nunn walked into the cardiac theatre one day and saw how we used venous pressure to guide transfusion after bypass and included me in the Faculty meeting at the RCS. Venous pressure monitoring took off after my paper was published and I think it is the only time that I feel to have changed clinical practice!]*

However, more technological work was to come.

The determination of the arterial pCO<sub>2</sub> was not easy in 1960/63 and a rebreathing technique was used, the concept was to equilibrate gases in an expired ‘air’ collection bag with gases in the alveoli in equilibration with gases in the pulmonary vessels. The first paper on this measurement technique was

about use of the technique in apnoeic patients [45], this involved the study of patients with tetanus at the King Edward VIII Hospital in Durban. These patients were totally paralysed – the present author has difficulty understanding the methodology as, even though the patients were “treated by total paralysis”, equilibration still appeared to occur – was this due to bulk movement of oxygen into the lungs with CO<sub>2</sub> being displaced upwards and outwards?

[Clarification from MKS - *We disconnected the ventilator and squeezed the O<sub>2</sub> containing reservoir bag manually until we had made a CO<sub>2</sub> rich mixture. We then returned the patient to the ventilator for a minute or so and repeated the rebreathing for about 6-10 breaths. The gas was then analysed on a simple Haldane [apparatus].*]

The second was a discussion of “Possible sources of error in the determination of arterial carbon dioxide tension by an interpolation technique”[46]. Calibration of blood samples was carried out using 3% and 7% carbon dioxide and Interpolation was used to determine patients’ PCO<sub>2</sub> value; in clinical use it was found that these values were lower than expected – the suggested reasons were a) the occurrence of metabolic acidosis during the storage of the blood and b) incomplete equilibration of the blood samples with the known concentrations of CO<sub>2</sub> / O<sub>2</sub> mixtures.

Other measurements commonly required, particularly for patients in intensive care units, were pH and blood gases. A review of their measurement and the sources of error using electrode systems was published in 1967 [47], the lead author being AP Adams.

[Personal comment from MKS: *Blood gas errors: When we first obtained an Astrup machine (the 1955 version with the mercury U tube to move blood to and from the equilibration chamber) I got Barbara Bird to measure the standard bicarbonate in a number of normal blood samples. To my surprise, the mean value was about 18 instead of 23. I did not believe our results and eventually learnt from Geoffrey Burton of Bristol that protein contamination of the electrode could cause low pH readings on blood. He showed that the electrode could be cleaned with pepsin and advocated using a standardized plasma preparation to check the electrode before use. When we followed his procedure we got the correct values for standard bicarbonate.*]

One of the aspects of pathophysiology associated with anaesthesia was alveolar collapse and subsequent hypoxaemia. Sykes and his team investigated the pulmonary vasoconstriction that accompanies alveolar hypoventilation (see below) and in 1977 (and also in 1981) evaluated new methods for measuring blood flow/ ventilation in the lungs. [48, 49]. The new technique involved the use of an isotope that allowed the distribution of blood flow between the two lungs to be measured continuously. In 1981 they compared regional ventilation using nitrogen-13 and krypton-81m in mechanically ventilated dogs

In 1980 oxygen measurement went under the 'microscope' [50]. It was found that even if the IMI oxygen analyser was properly set up the readings could be seriously affected by nitrous oxide. Ten years later it was pulse-oximetry [51, 52], first author Verhoeff; they used the computer simulator MacPuf to create three oxygen failure scenarios and compared the time of onset of hypoxia with the delays they detected between a fall in PO<sub>2</sub> and its detection by pulse oximetry. They thought that oxygen saturation might reach dangerously low levels before a pulse oximeter alarm occurred. The second paper was a report on the inaccuracy of SpO<sub>2</sub> readings in the presence of elevated concentrations of carboxyhaemoglobin and methaemoglobin. They describe the theory and an experimental in vitro test system using a blood circuit containing a model finger capable of pulsatile flow. The theoretical and experimental results were compared and "found to agree well" with carboxyhaemoglobin, but not so well with methemoglobin.

## **Monitoring**

Sykes had a major interest in equipment and measurement and therefore it is natural that he must have had views on monitoring. The first was in 1965. [53]on the monitoring of patients in respiratory failure, it is primarily a discussion about blood gas analysis in the situation where the hypoxic drive may be suppressed by moderately high concentrations of inspired oxygen. In 1988 he wrote a review article on 'Essential Monitoring' with many astute observations: "Studies of morbidity and mortality and critical incident analysis have revealed that the majority of complications associated with anaesthesia result from inadequate training or inadequate experience of the anaesthetist<sup>vi</sup>.

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<sup>vi</sup> Cooper, J. B., Newbower, R. S., and Kitz, R. J. (1984). *Anesthesiology*, 60, 34; Craig, J., and Wilson, M. E. (1981). *Anaesthesia*, 36, 933; Lunn, J. N., and Mushin, W. W. (1982).

Some are caused by tiredness or boredom, and others by lack of attention. Knowledge and experience are a function of the intensity and duration of training, but vigilance is, unfortunately, only generated by self-motivation.” and: “Because of the limitations of the individual monitors outlined above, it is necessary to use a combination of monitoring devices which is capable of detecting the majority of hazard situations”. This was an attempt to minimise false positives and false negatives. A letter followed in 1989 when a correspondent described a failure of a disconnection monitor. These were in the British Journal of Anaesthesia [54, 55]. Many of the comments still pertain today (2013).

A year later he wrote an introduction for the "Panel on practical alarms" (Fifth International Symposium on Computing in Anesthesia and Intensive Care) [56]. These were defining enterprises and probably structured monitoring for the coming decades.

### **Pulmonary vasoconstriction**

For 14 years, pulmonary vasoconstriction was the subject of much investigation - [57-77]. Pulmonary vasoconstriction, as a result of poor alveolar oxygenation, attenuates the effect on the arterial oxygenation by reducing blood flow to the poorly ventilated (oxygenated) parts of the lung. It would appear that an animal model (in both cats and dogs) was used to investigate the phenomenon and the effect on it of about 20 drugs.

The complex experimental set up is described in the first paper in 1972 [57]. In this study greyhound dogs ...."were anaesthetized with nitrous oxide-oxygen-halothane, intubated and ventilated with air and 0.5-1.0 per cent halothane..... The respiratory frequency was 20 per minute and the tidal volume was adjusted to maintain the end-tidal CO<sub>2</sub> concentration between 4 and 5 per cent. A normal acid-base status was maintained ... by the addition of 4.2 per cent sodium bicarbonate when required." End-expiratory pressure of 5–10 cm H<sub>2</sub>O could be applied when the chest was open. "When the pulmonary and

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Mortality Associated with Anaesthesia. London: Nuffield Provincial Hospitals Trust; Cooper, J.B., Long, C. D., and McPeck, B. (1978). *Anesthesiology*, 49,399.

femoral arteries had been cannulated, the halothane was turned off and anaesthesia maintained with intravenous injections of chloralose ... the animal inspired air either alone or with the inhalational anaesthetic agent under test." The description continues in great detail, all care being taken to avoid potential gas analysis pitfalls.

[Personal comment from MKS: *It took us four years to develop a satisfactory animal model. Initially we tried to keep the greyhounds asleep with electrical anaesthesia but they either convulsed or ran off down the corridor. We tried all sorts of complicated isolated lung perfusions but could not elicit HPV, probably because we used old greyhounds from White City dealers. Finally, I went to see a physiologist who introduced us to the standard model we later used.*]

The results showed that "alveolar hypoxia produced an increase in pulmonary vascular resistance in isolated cat and dog lungs or lobes perfused at constant flow. This response was abolished for varying periods of time by the administration of high concentrations of inhalational anaesthetic agents. In these preparations 5 per cent halothane caused pulmonary vasodilatation whereas 15 per cent ether, 1.5 per cent trichloroethylene and 79 per cent nitrous oxide caused vasoconstriction. Two per cent methoxyflurane did not cause a significant change in pulmonary vascular resistance. It is postulated that the abolition of the pulmonary vasoconstrictor response to hypoxia may increase the proportion of blood flowing through shunts or areas of lung with a low ventilation/perfusion ratio and so may contribute to a decrease in arterial oxygen tension during anaesthesia. The pulmonary vasodilatation or vasoconstriction produced by inhalational agents may augment this effect."

Sykes and his collaborators studied:

- a) Protamine / heparin mixtures - they "produced a rise in pulmonary artery pressure ... the pulmonary vasoconstriction produced by protamine may be partly due to a direct action on the pulmonary vasculature or to the release of vasoactive substances from the lungs." [58]
- b) Trichloroethylene - "It is concluded that trichloroethylene may increase arterial hypoxemia by reducing vasoconstriction in hypoxic areas of lung." [60]

- c) Methoxyflurane - "Methoxyflurane decreased pulmonary vascular resistance and depressed the pulmonary vasoconstrictor response to hypoxia." [61]
- d) Nitrous oxide - "Nitrous oxide, in concentrations of 50 per cent and 75 per cent, was found to produce a reversible depression of the hypoxic pulmonary pressor response." [62, 64]
- e) Diethyl ether - "Two per cent diethyl ether markedly reduced hypoxic vasoconstriction under all acid-base conditions, the hypoxic pressor response returning after wash-out of diethyl ether." [63, 65]
- f) Cyclopropane - "Cyclopropane was found to produce no significant changes in pulmonary vascular resistance or the pulmonary vasoconstrictor response..." [67]
- g) Dopamine/isoprenaline - "Dose rates of dopamine 25 micro-grams  $\text{kg}^{-1} \text{min}^{-1}$  and isoprenaline 0.25 micrograms  $\text{kg}^{-1} \text{min}^{-1}$  (which produced equal increments in the contractile force of the heart in dogs) produced a similar degree of depression of the hypoxic vasoconstrictor response" [68]
- h) Orciprenaline - "The hypoxic vasoconstrictor response was significantly depressed by an infusion of 1.0 micro-grams/kg/min of orciprenaline but not by a dose of 0.1 micrograms/kg/min." [69]
- i) "Infusions of nitroglycerine and sodium nitroprusside which produced the same decrease in mean aortic pressure produced similar decreases in hypoxic pulmonary vasoconstriction." [70]

After these drug aligned studies the team now investigated the effects of  $\text{FiO}_2$ ,  $\text{CO}_2$  and mechanical factors on the reflex [71, 72, 74]. "Repeated hypoxic stimuli produced a progressively greater reduction in the blood flow to the hypoxic lung and a progressive increase in  $\text{PaO}_2$ ." "It is suggested that the effects of  $\text{CO}_2$  on h.p.v. and  $\text{PaO}_2$  may be explained largely by the changes in alveolar oxygen pressure ( $\text{PAO}_2$ ) which are secondary to changes in  $\text{PACO}_2$ ." and "We concluded that the reduction in blood flow during lobar collapse is due predominantly to hypoxic vasoconstriction, but that this mechanism is augmented by the raised  $\text{PCO}_2$  and mechanical factors present during collapse." and "It is concluded that changes in local  $\text{pCO}_2$  during collapse may account for the greater diversion of blood flow from the lobe when compared with ventilation hypoxia."

Two papers in 1986 [75, 76] described the effect of lignocaine on the hypoxic pulmonary vasoconstriction reflex: "It is concluded that lignocaine reverses the depression of hypoxic pulmonary vasoconstriction produced by lobar ventilation with nitrous oxide..." and "... the subsequent infusion of lignocaine during 7% oxygen in nitrous oxide increased the response to a value which was not significantly different from that produced by 7% oxygen in nitrogen alone."

The mechanism by which dopamine alters blood flow distribution during lobar collapse was determined [77] - " It is concluded that the [the effect] produced by dopamine was due to a decrease in hypoxic vasoconstriction in the lobe secondary to an increase in mixed venous PO<sub>2</sub> and to vasoconstriction in the oxygenated lung".

Many other articles on this important pulmonary reflex were published [78-86]

This was a large body of work addressing the problem of hypoxaemia associated with anaesthesia and commonly seen in intensive care patients. There were many collaborators.

### **Lung ventilation**

Over a thirty-year period the unravelling of pulmonary physiology took place as it pertained to anaesthesia and intensive care. Some publications to do with oxygenation [87-89], two about differential lung ventilation [90, 91] (this was an investigation into the V/Q mismatch associated with IPPV with the patient (dog) in the lateral position using the equivalent of a double lumen tube); the first a presentation to the ARS and the second a full paper. If each lung was ventilated so that the EtCO<sub>2</sub>% in each was the same then the V/Q was as if the patient was supine. Six investigated the effect of the pattern of respiration on oxygenation [92-97] and later on the possibility of ventilation causing lung damage [98-100], one a comparative study, another a review; all these investigations of great importance to clinical practice.

### **Resuscitation**

His first publication on resuscitation has been described above [7] in the Medical Electronics section of the BMJ, "New Appliances". This described a resuscitation trolley with all the equipment required for lung ventilation and CPR. The second was about the organization of a resuscitation service [101].

The article was divided into "**Organization**" – a sub-committee of the Medical committee, convened by the Resuscitation Officer who is in charge of the day-to-day running of the service. **Aims:** management of cardiac arrest, collapse in the outpatient or casualty department, all postoperative patients, patients having myocardial infarct or Stokes-Adams attack, and other patients at special risk. **Treatment:** "Treatment is based on the principle that the person on the spot is responsible for diagnosing the arrest and for establishing artificial ventilation and an effective circulation: this is then maintained until more definitive treatment, aimed at restarting the heart, can be carried out by the duty surgeon and anaesthetist." **Training:** "It is obvious that both medical and nursing staff must be trained in the recognition and emergency treatment of cardiac arrest." At the Hammersmith these lectures were given twice yearly at the new intake of residents. **Procedure:** The on-the-spot clinicians start the resuscitation, 'phone the switch board, and if no responses in a short time a general cardiac arrest call is to be made over the hospital Tannoy! Life was simple then. The **results** of this service were then described – a seven year period from 1956-1963. Of 251 patients 34 survived. The three top categories were either during procedures, in the postoperative period or during induction of anaesthesia. It is interesting to note that between 1956-1961 there were 21 patients per year who received internal cardiac massage (13 survived); in the years 1962-3 no patients had internal cardiac massage from the start. However, there were 24 patients who started out having external cardiac massage and then proceeded to internal cardiac massage - only one survived. "One rather startling complication of external cardiac compression has been the rapid return of consciousness resulting from effective treatment. For this reason we have now added a supply of anaesthetic drugs to the cardiac arrest trolleys." **Conclusion:** "Every hospital should make its own arrangements for the emergency treatment of cardiac arrest."

Internal cardiac massage was obviously on the way out. The article that followed this in the journal was "Automatic External Cardiac Massage Machine" by V Keating.

A further report in 1966 covered the years 1963-1965 [102], the survival rate was almost identical – 13.1%. A year later a paper entitled "Resuscitation of the apparently dead" was published in *International Anesthesiology Clinics* [103]; an interesting title. This is a comprehensive (39 pages, 131 references) review of the causes, effects treatment and sequelae of cardiac arrest, including descriptions of the equipment that can be used.

## **Cardiopulmonary bypass**

Keith Sykes' was a cardiac anaesthetist at Hammersmith but not in Oxford<sup>vii</sup>, he published sixteen research projects on factors around cardiopulmonary bypass and cardiac surgery over 26 years.

1963 "Intermittent positive pressure respiration after open-heart surgery" [104].

1965, in *The Lancet*, two articles on post-perfusion lung syndrome [105, 106].

1966 "The elimination of carbon dioxide after total body perfusion" and "Pulmonary changes after extracorporeal circulation in dogs" [107, 108].

1967 "The effect of low molecular weight dextran and haemodilution on acid-base balance and lactate and pyruvate levels during cardiopulmonary bypass" [109]

1969 "The effect of varying inspiratory: expiratory ratios on gas exchange during anaesthesia for open-heart surgery" [110] and "The effect of varying inspiratory: expiratory ratios on gas exchange during anaesthesia for open-heart surgery" [111]

1970 "The effect of variations in end-expiratory inflation pressure on cardiorespiratory function before and after open-heart surgery" [95] and "The effect of mechanical ventilation after open-heart surgery" [112]

1974 "Cardiorespiratory effects of protamine after cardiopulmonary bypass in man." [113]

1978 "Cardiorespiratory effects of increased airway pressure during controlled and spontaneous breathing after cardiac surgery." [114]

1982 "Changes in colloid osmotic pressure with plasma albumin concentration associated with extracorporeal circulation. [115]

1983 "A vortex-mixing membrane lung for open-heart surgery or for prolonged respiratory support" [19] and "Initial in vitro evaluation of a pediatric vortex-mixing membrane lung" [20]

1985 and 1986 "Oxygen and CO<sub>2</sub> transfer of a polypropylene dimpled membrane lung with variable secondary flows" [21, 22].

1989 "A randomized comparison of total extracorporeal CO<sub>2</sub> removal with conventional mechanical ventilation in experimental hyaline membrane disease" [116]

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<sup>vii</sup> Personal communication – Pierre Foex

This body of work alone is worthy of respect – a thorough analysis of all of Sykes' work with critical appraisal (with an explanatory subset of chapters on the complex physiology involved) would entail a textbook all of its own. One book of his own (as co-author) was Principles of Clinical Measurement and Monitoring in Anaesthesia and Intensive Care with M D Vickers and CJ Hull.

**Some final words:**

In 1995, the last year he published, he wrote two articles, one on quality assurance in research [117] and the other titled "Recognition of the anaesthetist" [118]. In addition there was the re printing of a 1960 paper on Intermittent Positive Pressure in tetanus neonatorum; reprinted as a classic paper[119].

The quality of research article covered the fact that there were about 80 journals pertaining to anaesthesia, a high proportion of the papers being of "doubtful validity" and an estimated 1% being scientifically sound. The quality assurance issue starts with study design and continues through ethics committees, execution of the project and the analysis. Of projects signed off by the Central Oxford Research Ethics Committee only 59% had been published three years later. It was thought that 30% had not been published because of insignificant results, negative results or had been rejected by the journal's editor. Sykes thought that pilot studies were of importance because they highlighted the difficulties of the study and allowed the opportunity to modify the protocol, data collection and analysis. He was particularly concerned about bias, both overt and subtle, and the dangers involved in studies for the benefit of pharmaceutical companies.

The "*Recognition of anaesthetists*" editorial in Anaesthesia was about the fact that even in 1995 the anaesthetist still seemed to be a 'backroom' service provider and was losing out with regard to funding in the 'purchaser-provider' split in the UK. Anaesthetists were performing many important clinical and administrative roles but were still not recognised by patients as not only being doctors but being specialists. He advocated preoperative assessment visits and postoperative checks as a start to greater recognition by the public. He was of the view that patient education was an anaesthetist's role and that duplication of information was important to get information to the patient – interviews, booklets and videos would all reinforce in the importance, and potential hazards, of anaesthesia. He considered post-operative audits of

patients' experiences important, not only for them but as feedback for the service.

**A finale:** ...the reprinting of the 1960 paper on the management of tetanus neonatorum is good in that it does give us an inkling of Keith Sykes himself. A brief description of the encounter leading up to his work in 1958 in the King Edward VIII Hospital in Durban is interesting. He had £1000 to buy ventilators and analytical equipment; he had to sell his car to buy boat tickets to get his family there, let his home etc... and whilst there his asthma was a problem because of the humidity.

The intended work on adult tetanus did not succeed because the number of patients presenting with tetanus fell so they transferred their attention to the neonates. There were many physical problems to overcome with ventilators, humidification and tracheostomy tubes but the mortality fell from 84% to 44% and later 11%. Unfortunately, Pat Smythe and Arthur Bull pre-empted the publication of his results<sup>viii</sup> with a similar small study.

[Personal comment from MKS: *On the way back from Durban our Union Castle boat stopped in Capetown for a week and I gave a talk to the University department about the setting up of the Durban tetanus unit. Arthur Bull and Pat Smythe came up quietly after the talk and showed me the copy of the BMJ that had just been published containing their article announcing their 9/10 survivors! We were good friends for many years and they kindly stated that my rebreathing PCO<sub>2</sub> technique had helped improve their results.*]

Overall, a huge body of varied work is attributable to Keith Sykes and to the team around him.

He continues to write, notably in the History of Anaesthesia Society Proceedings, and has written a book, with John P. Bunker, called "Anaesthesia and the practice of medicine: historical perspectives" that was published in 2007. I enjoyed reading it.

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<sup>viii</sup> Smythe P and Bull A. British Medical Journal 1959;2:107

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[Further comments MKS...I think your comments about my motivation are correct. I have always been a keen clinician, gave anaesthesia for 5-6 sessions a week at both Hammersmith and Oxford and took my share of a 1 in 5-7 on call rota at both places. At Hammersmith we had plenty of SRs to deputise when I was travelling but at Oxford the other Consultants always insisted on my doing a swap if I was away so I ended up with a lot of on call when at home. I started using mechanical ventilation on post-op open heart and tetanus cases in 1960 and ran one of the first intensive care units at Hammersmith from 1961 to 69.

In Boston there was always a surgeon scrubbed to do internal cardiac massage before anaesthesia was started. The cardiac arrest service at Hammersmith (which I think was the first in the country) was started because one of the physicians who was doing bronchoscopies under topical anaesthesia biopsied the left atrium with fatal results and asked me to create an emergency team. I ran

*this service with lecture-demos to all departments every three months until about 1965. It is interesting that our survival rates approximated to those currently reported.*

*When running 12 operating rooms in the charity block in the Massachusetts General Hospital I had to supervise year 1 and 2 junior residents and nurse anaesthetists. I gained an amazing experience of anaesthetic complications and thereafter I took great interest in safety, chairing the AAGBI committee and working on British and International standards committees for over 30 years.*

*I was extremely fortunate in having good labs and an unending supply of potential researchers at both Hammersmith and Oxford. At Hammersmith I usually spent a day a week on animal work, ably assisted by Mr Chakrabarti, a highly intelligent émigré Indian Electrical engineer who could never be persuaded to service equipment but who nearly always managed to get it going again when pressed! He became interested in high frequency ventilation and transferred this interest to Joe Whitwam when I went to Oxford. Unfortunately, I did not have time to work in the labs myself at Oxford but I kept a close eye on the experiments downstairs and reviewed the data with the researcher at least every week. Within a year of going to Oxford, Clive Hahn, Pierre Foëx and I had 21 research fellows working on MRC, SERC and other studentships. About half were medical and the others mathematicians, engineers, and biochemists who divided their time between our labs and theirs. We continued to have 20-25 research students until I left in 1991.*

*I think most of my publications would come pretty low on the citation index as they rarely produced the ground-breaking results that others claimed and the only piece of apparatus named after me was the four-in-line reservoir bags filled with nylon pot scourers expired gas mixing unit that was known as Sykes's double-ended bra! However, the paper on venous pressure (which resulted from an invitation from John Nunn to speak at the RCS) did change clinical practice and was quoted quite widely at the time.*

*I think that teaching trainees to think and assess evidence was probably of more use to the profession than the research. The grilling that I gave the better FFA candidates was designed to identify those who would get a 9+ instead of awarding marks on the old school tie principle that was common at the time. The*

*books Respiratory Failure and Principles of Measurement were among the first in the field and sold well both here and abroad. Just before I retired an anaesthetist in Ireland presented me with a newly bound, dog-eared copy of the measurement book that he had used for the primary. The new title that was inscribed in Gold leaf was "The SHO's Bible"!]*