Jones JG
MD FRCP FRCA
Hon FANZCA

 [i]

Between 1968 and 1970 J Gareth Jones was lecturer in anaesthesia in Birmingham and, for the following four years, the North Senior Fellow at the Cardiovascular Research Institute, University of California, San Francisco.

He then became a senior scientific staff member in John Nunn's Division of Anaesthesia at the MRC Clinical Research Centre, Northwick Park Hospital, Harrow. However, his first research exposure (as a medical SHO) was in the MRC Pneumoconiosis Research Unit in South Wales.

"My bosses were Archie Cochrane (famous for Evidence Based Medicine), John Cotes (developed the open circuit oxygen breathing systems used by Hillary and Tenzing on the first Everest Summit), and John Gilson (who developed the RAF oxygen masks). After this I was a medical registrar specialising in cardiology and did [the]*MRCP* [exam]*".*

Between 1986 and 1991 he was professor in Leeds. He was then appointed foundation professor in Cambridge, linked to the Department of Medicine, and adjacent to the Department of Anaesthesia in Addenbrooke's Hospital[ii]. His work revolved around respiratory and cerebral physiology, the former on how anaesthesia is related to perioperative hypoxaemia and the latter on awareness and memory.

Jones JG was a Member of the Royal College of Physicians and was, therefore, more physician-inclined[iii] in his early career, and was heavily involved in respiratory physiology. "*From 1964 to end 1967 I was research fellow in Sir Melville Arnott's Dept Medicine in Birmingham. Here I did my MD*

[i] Photograph courtesy of JGJ. All text in italics is his.

[ii] J F Nunn. British Journal of Anaesthesia. 1999; 83(6): 916

[iii] A good anaesthetist needs to be a good physician but not all physicians would make good anaesthetists.

*(19**6**7) on Ventilatory Function, Distribution and Mixing of Inspired Gas. This involved use of a new rapidly responding respiratory mass spectrometer developed by the Australian physicist Kemp Fowler working with John West at Hammersmith. My supervisors were John Bishop and Gordon Cumming with grants from the US Air Force. Cumming was involved in studying the mathematics of branching systems, gaseous diffusion in the lung and employed both single and multi breath tests using analog and digital computing in data analysis."*

Whilst a lecturer in Anaesthesia in Birmingham he continued to work in the Dept of Medicine laboratories, being joined by S W Clarke. *"We studied the effect of gravity on the lung and studied gas flow in branching tubes and fluid mechanics of two phase gas liquid flow. Some of this was done with the RAF at Farnborough using the human centrifuge, pressure chambers and vertically rotating chairs."*

He wrote four papers with Gordon Cumming [1-4]. The 1966/7 studies were about nitrogen clearance curves [1]. Curves were generated from a physical model and volunteers breathing oxygen. They were able to measure one litre of lung volume with a standard deviation of 10 ml. Following this work with normal subjects they studied patients with chronic bronchitis [3]. They used two techniques, the multi breath technique where nitrogen was washed out with oxygen and the single breath method using either nitrogen washout or 50ml argon boluses inhaled to different depths down the airways to study diffusion. This work was carried out under contract to the European Office of Aerospace Research (OAR), U.S. Air Force.

1969 was the transition year, a very busy year; six papers were published in high quality physiology journals and two in the British Journal of Anaesthesia. There was a presentation at an Anaesthetic Research Society (ARS) meeting in London in the previous November (but published in the BJA in February '69, "*Two-phase gas-liquid flow in airways*" [5]) and then a later one at an ARS in Birmingham which was on the "*Influence of age on basal airway closure*" [6].

The first 15 years of Jones' time in anaesthesia were spent mainly on the changes in lung function that occur during anaesthesia.

In November 1970 there was an Anaesthetic Research Society meeting in London and there was a presentation on "*The effects of nitrous oxide uptake on alveolar oxygen concentrations*" [7]; it was published in the BJA in the following

February. As was common a full paper was published later in the year [8]. These were tricky experiments. Volunteers, inaccessible and completely enclosed in a body plethysmograph with an arterial line coming out through the wall, were given a variety of concentrations of nitrous oxide and many variables were measured as they lost consciousness. They showed an increase in alveolar oxygen tension which was proportional to the inspired N_2O concentration. The difference between the alveolar and arterial oxygen doubled. The reasons are complex but involve *"lung shrinkage"* (reduced functional residual capacity) which also caused an increase in the alveolar/arterial difference; this supported the work of Stoelting and Eger (1969)[iv]. Alveolar oxygen concentration increases and so adds a small degree of safety.

In 1970 he went to the USA. "Although I had reverted to physician/physiologist I was immediately involved with John Severinghaus in a project to induce high altitude pulmonary oedema (See "The Hypoxia Hilton", on Google) *[9]*. Back at sea level my main research was to elucidate the mechanism of expiratory flow limitation in the large airways (with R Fraser and J Nadel) *[10-12] [see RCA Bulletin article[v]]*. This was my main project resulting in an understanding of the mechanism of expiratory flow limitation. Our paper was seen at the review stage by others who, although quoting our work in their subsequent paper, claimed to have discovered the Wave Speed theory of flow limitation which was none other than our own equation. This work was more than 30 years ahead of its time being relevant to modern tracheal transplantation.

Some of the subjects studied were -

The effect of pre-inspiratory lung volume on the result of the single breath O_2 test [13]

Respiratory gas exchange in patients with spontaneous pneumothorax [14]

Postural changes in pulmonary ventilation [15]

Inhaled argon boluses in man [4]

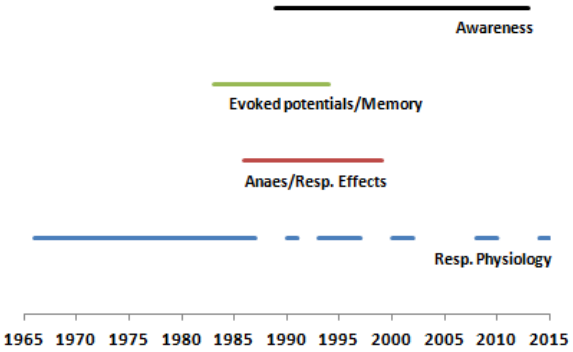
[iv] Stoelting and Eger. Anesthesiology 1969;30:273-7, the concentration of alveolar gas – the second gas effect.

[v] RCA Bulletin 2003, 17, p850

Oscillations in expiratory gas flow during a forced vital capacity manoeuvre [13]
The effect of expiratory flow rate on regional lung emptying [16]
Effect of acceleration on regional lung emptying [17].

This last one is of particular interest - it was collaboration between the Department of Medicine, Queen Elizabeth Hospital, Birmingham and the Royal Air Force Institute of Aviation Medicine, Farnborough. It was determined that there was virtually no gas-trapping when extrapolated to zero Gz but progressively larger volumes of trapped gas as acceleration increased to 4Gz causing increased V/Q abnormalities.

The work pattern over the years:



Choice of journals:

British Journal of Anaesthesia	(47)
Journal of Applied Physiology	(14)
Anaesthesia	(13)
Anesthesiology	(5)
Clinical Science	(4)
Respiration Physiology	(3)
Lancet	(3)
Journal of Physiology	(2)

In 1976 they (Jones and Minty) studied the contribution of the chest wall and the abdomen to breathing; this was presented at another ARS meeting, this time at Northwick Park [18]; as previously, the work was published in full later, three years later [19, 20]. They created a mathematical model of the chest wall, an analogue computer, and used mercury-in-rubber strain gauges around the body to measure the changes in circumference. The subjects were assessed before and after anaesthesia. They determined the error between the computed tidal volume and that actually measured at the mouth and it was 8%. The contribution of the rib cage to tidal breathing was from 5 to 42%.

The second paper was about the mechanics during halothane anaesthesia. Whilst awake, movement of the abdomen/diaphragm complex was responsible for 70+% of the tidal volume (rib cage 5-30%). Halothane anaesthesia caused a reduction in the contribution of the rib cage. They showed an increase in abdominal volume and a reduction in rib cage volume at the end of expiration. It is a complex dynamic situation but it was concluded that halothane predominantly affected the rib cage musculature predisposing to paradoxical ventilation. It was also suggested that the reduced lung volume might be due to "loss of postural control of the chest wall and a central shift of blood volume".

In publications in 1976 (ARS) and 1978 Jones and Minty also reported on the comparison of active and passive closing volume manoeuvres in conscious subjects [21, 22].

In 1978 there were two studies about the lower airways [23, 24]; they were adjacent in the same journal. The first was on narrowing of dependent airways and the second on the effects of pulmonary venous congestion on the airways.

The first was a study of anaesthetized dogs; they assessed closing volume[vi] and used tantalum bronchography to measure the calibre of airways. It demonstrated that the elasticity of lung parenchyma and vagal induced changes in airway calibre, affect closing volume. They showed that there was a

[vi] Closing volume is the volume of lung inflated when small airways in the dependent parts of the lung begin to collapse during expiration. In normal health, closing volume is less than FRC and accounts for the residual volume (RV) of the lung at the end of expiration.
www.frca.co.uk/article.aspx?articleid=100423

vertical gradient of airway diameters in the supine lung and a "*preponderance of the effect of vagal stimulation in the lower zone*"; this is where the lung recoil is least. It was suggested that because halothane virtually abolishes the effect of vagal stimulation on closing volume and on airway resistance makes it useful when intubation is required for severe bronchospasm.

The second study measured changes in airway calibre when there was pulmonary congestion; a balloon was placed in the left atrium. Closing volume increased by about 50%. Seven out of 10 dogs had impaired gas exchange; this was not due to increased lung water. In a second group disabling of the vagus returned the closing volume to baseline values. It was also shown that isoprenaline abolished the effect. It was concluded that "*the vagus mediates the changes in lung mechanics associated with pulmonary vascular congestion*".

"*Returning to the UK in 1974 I was involved in Intensive Care which meant a major change in research direction. I started studying alveolar wall injury in relation to ARDS. I developed a new method using Technetium labelled chelates (DTPA) and other molecules to study alveolar injury and recovery after acid aspiration and fat embolism in animals . Modifying the technique for use in man we were the first to show in the Lancet that symptomless smokers had very leaky lungs (this paper has been very extensively quoted)* [25]*. This finding influences the administration of aerosolised insulin in diabetic smokers. Widdicombe* [vii] *... described the salient features of our physiological findings, but there are many overlapping aspects of my work in this period including fat embolism, acid aspiration, cigarette smoke inhalation, complement activation, fire smoke inhalation. In the latter we collaborated with the Royal Navy and the MoD Porton Down (Beeley, Minty* [26-28] *) studying the effects of high dose steroids after smoke inhalation. The results were used in the Falklands in soldiers with smoke injured lungs. During this period I returned to San Francisco in 1977 to work with JF Murray on lung injury with further papers on pulmonary edema, lung permeability etc."* [29-31]

"Returning to the UK in 1978 I developed a new method for measuring airway resistance in patients anaesthetised with different general anaesthetic agents (Lehane, Jordan, Royston, Altman) [32-34]*. This used forced airflow oscillation and on-line computing to derive resistance. The work shed light on change in FRC and hypoxaemia during anaesthesia. During this time we were also studying ventilatory control (with various novel methods) and the effects of*

[vii] Widdicombe J J Appl. Physiol. 82(1): 3–12, 1997

morphine, morphine antagonists, diazepam and sleep (Catley, Jordan, Royston, Thornton, Heneghan). This was both in volunteers and in post op patients. This marked a step forward in realising that post-op hypoxaemia was the result of apnoeic periods, sleep and ventilatory depression with opioids. Submitted to Anesthesiology the paper was at first rejected by three reviewers (who thought it too novel) but, without protest on our part, later accepted by the Editor." [35]

In 1984 [36] changes in lung volume and their affect on PAO_2-PaO_2 during anaesthesia were investigated. The established wisdom was that the decrease in lung volume during general anaesthesia caused an increased oxygen tension gradient between alveoli and blood. The lung volume in anaesthetised patients was increased by tilting the patients head-up. There was no improvement in PAO_2-PaO_2 and changes in cardiac output made no difference either.

The theory that the impairment of gas exchange in anaesthetized man is caused by abnormalities of dependent lung ventilation due to abnormal diaphragmatic mechanics was further investigated in 1985 [37]. In this study of abnormal gas exchange in rabbits (induced by reducing lung volume to residual volume) two methods of increasing the lung volume were employed, the use of positive end-expiratory pressure (PEEP) and phrenic nerve stimulation (PNS). PNS produced greater movement of the diaphragm and improved gas exchange significantly more than PEEP. It was concluded that it supported the theory abnormal diaphragmatic mechanics contributed impaired gas exchange during anaesthesia.

In 1996 two reviews were written about the airways and anaesthesia [38, 39].

The next category is more clinical – pulmonary dysfunction associated with anaesthesia.

Going back again to 1985 the respiratory effects of postoperative analgesic regimens were assessed [35]. One group received intravenous morphine and the other received bupivacaine regional anaesthesia. There was comparable analgesia throughout but the respiratory effects were different. About 2/3 of the patients receiving morphine had 456 episodes oxygen desaturation less than 80%. The patients had obstructive apnoea, paradoxical breathing and periods of slow ventilatory rate. The difference was marked; those patients who had regional anaesthesia never had oxygen saturation less than 87%. It is

obvious that regional anaesthesia has a greater margin of safety compared to the continuous administration of morphine.

This was supplemented by a paper titled "*Episodic postoperative oxygen desaturation: the value of added oxygen* [40]. Postoperative analgesia with intravenous morphine was monitored continuously for changes in breathing pattern and arterial oxygen saturation. Patients breathed either air or 28% oxygen for alternating two-hour periods. Although oxygen did not change the incidence of abnormal respiratory patterns oxygen desaturation below 80% did not occur.

An editorial in the August BJA 1987 was on "*Anaesthesia, and atelectasis: the role of V_{TAB} and the chest wall*" [41]. V_{TAB} is thoraco-abdominal blood volume. This editorial lays out the various thoughts on the aetiology of intra-operative respiratory dysfunction.

A review in *Anaesthesia* in 1990 [42] on the mechanisms of perioperative hypoxaemia was thought to be mainly due to reduced muscular tone of the chest wall and changes in bronchomotor and vascular tone. These changes persisted into the postoperative period and their effects were enhanced by episodic obstructive apnoea which, in turn, was enhanced by opiate analgesics. Oxygen reduced the degree of resulting hypoxaemia. In the same year was a paper on postoperative hypoxaemia, it was a comparison of extradural, I.M. and patient-controlled opioid analgesia [43].

In 1991 he moved to Cambridge. *"In Cambridge, with David Sapsford, we also developed a new method for measuring, non-invasively, shunt and ventilation perfusion ratio. We applied this in ARDS patients, in patients during thoracotomy and used it to predict instability in oxygen saturation in the post operative period (Roe, de Gray)* [44, 45]. *Later I showed that it could be used in neonates (H. Smith)* [46] *and after fat embolism (Newell)* [47]. *After I retired I studied the effect of downstream pressure on oxygen delivery by venturi devices* [48] *and continued to use the Gas Exchange method in Edinburgh infants with bronchopulmonary dysplasia (Stenson, Quine, Rowe)* [49, 50]. *This method is now being used to improve targeted oxygen delivery in infants with damaged lungs. I have shown that it can predict the likelihood of in-flight hypoxaemia in pressurised aircraft (Jones, Bakewell, Heneghan, Jones, Snape)* [51]."

1991: The effect of nitrous oxide sedation on breathing and oxygenation (using pulse oximetry) after hyperventilation to a $PE'CO_2$ 3kPa was studied [52]. This was below the apnoeic threshold. Those who breathed nitrous oxide all became apnoeic and their oxygen saturation fell to an average

of 75%. Those breathing air did not become apnoeic but desaturated to an average of 92.5%. Postoperative hypoxaemia after general anaesthesia or sedation may be explained by this apnoeic effect and its importance in obstetric patients was stressed.

In 1993 the relationship between inspired oxygen partial pressure and oxygen saturation (P_IO_2 and SaO_2) was explored [53]. A complex, ideal lung, physiological model was created including the effect of shunt and V/Q effects, these involved nine compartments representing the variability of V/Q, and blood supply. Depending on the model's settings the plots of P_IO_2 vs. SaO_2 caused changes in the shape of the ideal curve in specific ways so that a series of simple measurements of P$_I$O2 and SaO_2 provided information regarding shunt and V/Q abnormality.

Four years later this technique was used to study gas exchange during thoracotomy [45]. A plot of P_IO_2 and SaO_2 was used to determine the shunt and ventilation/perfusion ratio. There was an increase "*... in shunt from 13.8% to 20.8% and a worsening ventilation/perfusion ratio from 0.5 to 0.2*". The technique enabled an assessment of shunt and V/Q and the prediction of SaO_2 at different values of SpO_2.

At the same time gas exchange during and after anaesthesia for upper abdominal surgery was investigated [54]. P_IO_2 was varied to produce a plot of P_IO_2 vs. SpO_2. Thirty hours after surgery the changes were such that it was concluded that the shunt and V/Q abnormalities during anaesthesia correlated with the SpO_2 30 h post-operatively. It was suggested that the technique could be used to identify patients at risk.

Finally, in this group, is a study of gas exchange following fat embolism after trauma [47]. As above they quantified shunt and V/Q mismatch over time. They both improved over a week but deteriorated after general anaesthesia for surgery.

This was obviously a very sophisticated analytical method. To the best of my knowledge it has never been introduced into clinical practice.

And now for something completely different:

"The next phase was Depth of Anaesthesia. This work is reviewed in Ghoneim's book "Awareness during Anaesthesia". I was probably the first to produce a booklet on Awareness under Anaesthesia (ICI Pharmaceuticals, Anaesthesia Rounds No 21, 1988). I was joined by Christine Thornton and we focussed on developing EEG methods for measuring the graded effect of various

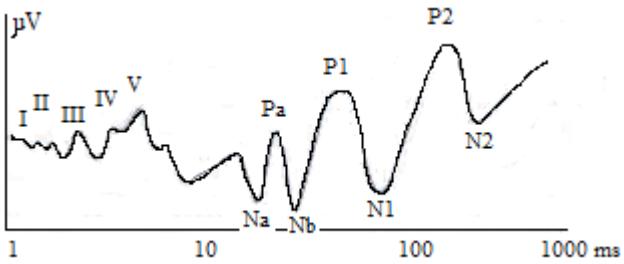
general anaesthetics on the brain. The Brain Stem response in the Auditory evoked potentials was the first part of the study and later this moved up to the middle latency (early cortical) responses. This was later taken up by Schwender et al. in Germany and by Kenny et al.

Thornton continued this work in London when I moved to Leeds and later she showed that working memory was very sensitive to 0.2 MAC equivalent doses of anaesthetic. We (Baddeley, Andrade, Sapsford, Munglani) [55-58] *independently showed similar results in Cambridge and developed the Coherent Frequency in the EEG as a measure of depth* [of anaesthesia]. *It is an extraordinary sight to witness the videos of experiments where volunteers are given sub MAC doses of general anaesthetic. They, appear to be fully conscious, respond to questions and painful stimuli yet a few minutes after the anaesthetic is discontinued have no recall of the conversations or the painful experience."*

Evoked Potentials

C Thornton was involved in seven of these publications about evoked potentials, six as first author.

Evoked potentials are detected in the brain in direct response to specific stimuli; aural, visual or motor. Below is a schematic diagram of such an evoked potential waveform.



Brainstem waves between 1 – 10 ms
Early cortical (or middle latency) waves 10 – 100 ms
Late cortical > 100 ms
Event related potential occurred at 300 ms (P2 or P300)

In 1983 the effect of enflurane concentration on the auditory evoked response (AER) was studied [59]. Anaesthesia was with 70% nitrous oxide in

oxygen, and the enflurane concentration was increased from 0 to 1% over half-an-hour. The latencies of all waves, and the interpeak latencies, showed significant increases. The amplitudes of Pa and Nb showed significant decreases. The study demonstrated a dose-related direct effect of enflurane.

This work was carried on in 1984 [60] with the addition of halothane to the study. Anaesthesia was induced with thiopentone and anaesthesia was again maintained with 70% nitrous oxide in oxygen. Halothane was given up to 2.5% and enflurane up to 5%. Linear dose-related increases were seen, with both agents "*in the latencies of waves III, V, Pa and Nb and the interpeak intervals I-V and III-V, with decreases in the amplitudes of Pa and Nb.*" When the agents were discontinued a reversal of the changes occurred in some or all of these waves. It was clear that halothane and enflurane delayed neural transmission and the effects "*approximately related to their known anaesthetic potencies*".

A depth of anaesthesia monitor has been the goal of many researchers; for volatile agents it is not a major problem as modern monitors can measure the agent in exhaled breath but it would be welcome for use with intravenous agents where the drug concentration can only be approximated. In 1986 [61] the AER was measured during anaesthesia with nitrous oxide and an infusion of Althesin. Blood concentrations of alphaxalone were measured and there were dose-related changes in latency and amplitude of waves Pa and Nb. There were no changes in the brainstem waves. This supported previous work that suggested that Althesin did not work below the superior colliculus.

In 1987 isoflurane was compared with halothane and enflurane [62]. When compared on a MAC-based basis (a measure of potency) no differences were found on the effect on the amplitude of the early cortical waves although latencies were different. The consistent dose-related effect on the amplitudes of the cortical waves implies, and they actually suggest, "*...that the AER could be a promising index of the depth of anaesthesia".*

A good depth of anaesthesia monitor has to respond not only to the anaesthetic agent (inhaled or intravenous) but also in a consistent way to surgical stimulation. In 1988 patients were studied during anaesthesia with thiopentone, nitrous oxide, halothane and pancuronium [63]. The anaesthetic concentration was held constant and baseline AER recordings were made. With surgical stimulation the amplitude of waves Nb and Pb/Pc increased. They again suggested that AER "*may, therefore, provide a useful index of depth of anaesthesia, which is the balance between the effects of surgical stimulation and anaesthetic depression on central nervous system activity*". However, they also

described "*unambiguous autonomic responses" that were not correlated with changes in the AER.*

Tunstall's isolated forearm test[viii] is a documented test for wakefulness during anaesthesia. This was used in 1989 to assess the AER as an indicator of wakefulness [64]. The concentration of nitrous oxide was reduced during anaesthesia and when Nb latency decreased below a pre-fixed threshold four of the patients (out of seven) indicated awareness. Volatile anaesthesia abolished the response, increasing the Nb latency. They considered the three wave AER pattern to be "associated with a depth of anaesthesia at which awareness occurs".

The AER was also used to assess the ability to perform a task and to remember it; this was in 1991 [55]. Subjects with headphones had to respond to a random burst of sound. They breathed either air or increasing concentrations of nitrous oxide. Amplitude, latency of the P300, and minimum reaction time all changed in a dose-dependent manner. Even at concentrations of nitrous oxide where memory of the events were absent a majority of the subjects still pressed the button (akin to a positive Tunstall test without any memory of the event). It was thought that the P300 wave could be useful as a tool for studying awareness during anaesthesia.

In 1993 they 'converted' the complicated arrays of latencies and amplitudes into one measure – the coherent frequency [65]. The coherent frequency was calculated from a Fast Fourier Transform of AERs – the fundamental frequency being very large compared with the 1st and 2nd harmonics. In brief the coherent frequency and psychological tests changes in a consistent way to 'depth of anaesthesia' and stimulation.

There is obviously an overlap between this and the following section but the keyword used for the references below was 'memory'. Interestingly they are either editorials or reviews.

An editorial is defined as an article expressing an opinion on a topical issue and a review is an attempt to summarize the current state of understanding on a topic.

[viii] Tunstall ME. British Medical Journal 1977; 1: 1321.

Awareness/Memory

The first of eight editorials/reviews was in 1986, in the BMJ [66]; "*Hearing and memory in anaesthetised patients*". It outlined the understanding of short term and long term memory, conscious awareness, unconscious awareness and unconsciousness. These were linked to the ability to recall events. It was pointed out that autonomic responses did not correlate with episodes of awareness. The questions to be asked were; '*What was the frequency of awareness?*' and '*Can depth of anaesthesia be measured?*' It was said that anaesthetic agents universally depress the cortex but only some depress brain stem activity and so the third question was '*Can the AER be used to detect blockage of the auditory pathway?*'

Five years later (1991) there was an editorial on '*Awareness and memory in anaesthetized patients'* in the BJA [67]. In a previous article by Prys-Roberts unconsciousness was described as a threshold event. Jones disagreed and considered that the onset of unconsciousness was a continuous spectrum. It included a review of learning mechanisms and the concept of "*pre-conscious processing of sensory information*"[ix]. It also described the effect of unconscious pre-conditioning (positive suggestions during anaesthesia) that helped with postoperative recovery. Evidence suggested that the affects of anaesthesia are mainly on short term memory and that cortical waves are good indicators of depth of anaesthesia.

Another BJA editorial in 1991 [68] was on '*Conscious awareness during general anaesthesia - what are we attempting to monitor?'* Tunstall's isolated forearm technique was described as the closest available to a gold standard method for comparing methods of determining depth of anaesthesia. Of the techniques being studied AER seemed the most promising – **but,** some previous work (in 1964 by Libet et al [x]) demonstrated that before conscious awareness can occur, 'neuronal adequacy' has to happen; this takes up to 500ms. However, conscious awareness occurs at about 50ms (early cortical evoked response). It is complicated – reaction times may only take 200ms, so conscious awareness not necessary for 'automatic' reactions. The time during which 'neuronal adequacy' develops needed to be investigated and so the recent work the Jones' team did with N_2O on P300 was cited [55]. The effect was to maintain reaction time but no registration of the event in memory. It

[ix] Dixon NF. Preconscious Processing. Chichester; John Wiley and Sons,1981

[x] Libet B et al. J of Neurophysiology 1964;27:546-578

was pointed out that neurophysiology was the way to get to a depth of anaesthesia monitor, not peripheral affects like oesophageal sphincter pressure.

A review article was published in 1992 [69]. Very briefly - general anaesthesia causes cerebral depression; anaesthesia can be "light" or "deep"; surgical stimulation may arouse a patient; it is difficult to detect conscious awareness; the median frequency (10Hz when conscious) should be below 5Hz to avoid a response to verbal command; the AER may be used to assess "depth of anaesthesia" but it was not yet certain which features were the most reliable.

There were another two such articles in 1994, one in the BJA [70] on '*Perception and memory during general anaesthesia*' and one in the BMJ [71], '*Memory of intraoperative events*'. The BMJ has a general readership, rather than the specialised readership of the BJA, but there was a public interest and anxiety in the matter of awareness during anaesthesia, the incidence being estimated at 1:10000. In the 1960s it was suggested that the anaesthetic technique using unsupplemented N_2O had an incidence of 0.6%[xi]. This was a general overview for the BMJ's readership.

The BJA article was in a Postgraduate Educational Issue and was therefore much more detailed. Jones estimated the incidence of awareness without pain as 4/1000 in obstetric patients and 2/1000 in non-obstetric patients. He described the use of clinical signs for assessing the risk of awareness – particularly respiratory sinus arrhythmia (RSA) as this did have a neuronal (vagal) basis from the brainstem. He stressed the importance of work by Schwender[xii] . The importance of the timing of the Nb wave determined the state of consciousness and memory. It was in this article that the coherent frequency was highlighted and it was said that if the coherent frequency was less than 10Hz and the middle latency waves were isoelectric then both consciousness and implicit memory were abolished.

If you want a real overview of the topic read this review of 1997 [72]. It discusses the structure of memory (using slightly modified nomenclature than previously – declarative (explicit) and non-declarative (implicit) memory and working memory). Jones was concerned that awareness remained a serious complication of general anaesthesia. If during an apparent adequate

[xi] Hutchinson R. BJA 1960;33:463-9

[xii] Schwender D. Wachheit Während Narkose. Wiesbaden: Wissenschaftliche Verlags Abteilung Abbott GmbH, 1989, 1-136

anaesthetic an adverse implicit memory was retained, postoperative behaviour might be altered and postoperative recovery influenced. The article includes details about use of the lower oesophageal sphincter as a measure of depth of anaesthesia, the frontalis electromyogram, RSA, the processed EEG (including BIS) and the AER (transient and steady state). The coherent frequency was the flavour of the month and it was said that consciousness was lost at 20Hz.

1998: This review covered much of the research covered before but addressed the problem stated in the title "*Is amnesia for intraoperative events good enough?*" [73]. Many drugs produce profound amnesia and so, does it matter if the patient is in pain during the procedure if they can't remember it afterwards? If abnormal emotions were to be found only after 'light' anaesthesia then increasing the depth of anaesthesia should be considered beneficial. If they occur regardless of the depth of anaesthesia then more analgesia and postoperative support should be considered. The last sentence was "*Amnesia may not be good enough but it may be the best we can achieve without further research"*.

A couple of years later, on a slightly different tack, the investigation of saccadic eye movements was reviewed. Saccadic eye movements are rapid movements by both eyes that we use routinely for scanning words and faces, and our surroundings, to build up a picture of our surrounding world [74]. The review was an evaluation of the efficacy of peak saccadic velocity as a measure of sedation. The physiology and pharmacology of eye movements was discussed and it was thought that saccadic eye movements could be used as a monitor of anaesthetic sedation. Two years following this review, in 2002, Carpenter et al. published a study on the effects of sevoflurane on saccadic eye movements [75]. The double-blind experiments involved breathing either 0.15% end-tidal sevoflurane, in oxygen, or pure oxygen. As might be expected the pure oxygen had no effect but the sevoflurane caused increased median latency of the saccadic movements. Thus it was considered that it might be possible to use these measurements to determine impairment following sedation.

In May 2005 there was a letter in the Bulletin (No. 31) of the Royal College of Anaesthetists from "*JG Jones, Formerly Professor of Anaesthesia of Cambridge University*". This was in response to a previous article on awareness by Absalom, Siegmeth and Bergmann. He was putting forward the view that if

"*profound analgesia and amnesia will do*" then measuring depth of "*unconsciousness may owe more to commercial zeal than clinical need*" [Paraphrased]. He was highlighting the reported incidence of awareness as being between 1:80,000 and 1:90,000 and that the costs of BIS monitoring was not trivial. He said that "*almost £1,000,000 would be spent to detect/prevent one case of debilitating awareness.*" The authors responded – in brief – "*there is no evidence that awareness without recall does not affect clinical outcome*" and that patients expect an anaesthetic in which there is lack of awareness.

Eight years later, in 2013, there was a similar communication [76] following a major study on awareness during anaesthesia from Oxford (Pandit et al Anaesthesia 2013; 68:343-53). This showed that awareness during anaesthesia was much less common than had been suggested. It also confirmed a similar claim made by Agarwal and Jones JG in Ghoneim's book (see above). Once again, a statement against the universal use of depth of anaesthesia monitors, the National Institute for Health and Clinical Excellence [should not] consider mandating such monitoring.

Other 'consciousness' related papers: [77-79]

Miscellany:

The need for basic sciences to the understanding and practice of everyday anaesthesia: [80]

This was an audit of the attitudes of post-fellowship (examinations) anaesthetists about Basic Sciences in the part I examination for the FRCA. Sixty five percent of the basic science syllabus was considered essential. The topics considered irrelevant were biochemistry, endocrinology, membrane theory and immunology. "*Paradoxically, there were many topics which anaesthetists regarded as essential but on which they were unable to give a tutorial*". It was suggested that the syllabus was overloaded with detail irrelevant to clinical practice.

Jones personal 'trek' through research can be seen in the Bulletin of The Royal College of Anaesthetists (No.8, July 2001); this one covers his time in Cardiff, Birmingham, work at Farnborough and the decision to go to San Diego. A second one in 2003 (Bulletin 17) deals with discoveries in America. Both are a good read. Bulletin 14 (July 2002) "Behind the scenes at the Final exam". Bulletin 52 (November 2008) "No Jekylls at Hyde Terrace"

about his time in Leeds and Bulletin 84 (March 2014) "The CRC Division of Anaesthesia". All a must read, containing much hilarity.

Gareth Jones was a member of Council of the RCA and Editor of the RCA Bulletin, he was a co-editor (with Ian Hindmarch and E. Moss) of one book; Aspects of Recovery from Anaesthesia (A Wiley Medical Publication) 1987. He also wrote a chapter on pulmonary physiology in Tom Healy's (and Paul Knight's) edition of the Wylie Churchill-Davidson's text book[xiii].

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The work by Jones and his co-workers obviously falls into two main categories. Respiratory physiology was his forte and the research work reported was complex in theory and difficult to do in practice. Notable outcomes – regional anaesthesia less detrimental to postoperative oxygenation than opiate infusions, supplemental oxygen is good and not smoking 48 hours prior to surgery is also good. The work investigating 'depth of anaesthesia' was also complex and absolutely fascinating – particularly some unravelling of the problem of awareness and memory.

This is a vast body of work and the author admits to not reading a large majority of the material. However this will have given a glimpse of the research carried out in its many forms and places. I would like to thank Gareth Jones for his help with the final amendments.

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